Science Indicators 1976

National Science Board

1977

NATIONAL SCIENCE BOARD

Science Indicators Unit

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Science Indicators 1976

Report of the
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Letter of Transmittal

September 30, 1977

My Dear Mr. President:

I have the honor of transmitting to you, and through you to the Congress, the Ninth Annual Report of the National Science Board.

In this Report, *Science Indicators—1976*, the Board presents the third step in the process begun with *Science Indicators—1972* of developing indicators of the state of science in the United States. Our goal is a periodical series of indices of the strengths and weaknesses of science and technology in the United States and the changing character of that activity. We hope that by contributing to the understanding of the scientific enterprise itself we will strengthen its forward thrust, illuminate its significance, assist in the examination of its problems, and thereby increase its role in the resolution of issues of great national concern.

The indicators in this Report deal primarily with resources—human and financial—for research and development. It deals as well with measures of some of the impacts and contributions of research and development to the welfare of the Nation. In our continuing use of these indicators, we are broadening our study of their characteristics and plan to describe our progress in subsequent Science Indicator reports.

Respectfully yours,

Norman Hackerman
Chairman, National Science Board

The Honorable
The President of the United States

Contents

Introduction

In 1968 the Congress directed the National Science Board to assess the status and health of science, including such matters as national resources and manpower, in reports to be rendered to the President for submission to the Congress. In 1973 the Board initiated the *Science Indicators* series, and in 1976 a joint committee of the Congress indicated its continuing interest in this particular series.[1] *Science Indicators—1976* is the ninth such annual report and the third in the *Science Indicators* series. With it, the Board continues its effort to describe quantitatively the condition of science and research in the United States.

The Report

This report represents a stage in the continuing effort to develop indicators of the status of science and technology in the various sectors of the U.S. economy. Science and technology are also examined in the international context. The intent of the present report is to select indicators of significant parameters of U.S. science and its related technology, and present them clearly and precisely with the appropriate caveats. Because the report has a great many users with different needs and points of view, the interpretation of the indicators is left mainly to the reader.

The report has been patterned after *Science Indicators—1974*[2] with the following differences:

- Some new indicators were added and a few previously included were deleted, after an evaluation of their usefulness, statistical significance, and reliability.
- Some of the numerical data are different because of changes in some classifications and the acquisition of more accurate information.
- Documentation of data sources is more complete, with additional references provided for those readers who are interested in examining further the topics discussed in this report.

[1] House Report 94-1689, 94th Congress, 2nd Session, September 27, 1976, p. 16.

[2] *Science Indicators—1974*, National Science Board (NSB 75-1).

The indicators selected for this report are presented in six chapters, including an expanded treatment of some topics such as patents, the U.S. role in international technology transfer, the impact of company size on invention and innovation, and the scientific publication patterns of U.S. authors. The time span covered by the indicators of the scientific enterprise ranges from the early 1960's through 1976 whenever feasible.

Each chapter begins with a set of indicator highlights which briefly summarize the major indices of that chapter. It should be noted that these highlights often omit the caveats and explanations which appear in the text itself. In the text the indicators are presented in graphic or tabular form and are more fully discussed. The appendix consists of detailed data tables which are referenced by the figures and tables of the text. These appendix tables usually provide more complete and extensive information. A subject-arranged list of indicators has been provided for the reader's convenience.

The ongoing task of identifying and creating useful and sound science indicators will continue since it offers the potential for a more enlightened public science policy. We have been encouraged by the high level of interest shown in the previous *Science Indicators* reports both domestically and abroad. The Board invites those interested in the use and development of such indicators to become involved in the process and participate in this effort to better understand the scientific enterprise.

Indicators of Science

The purpose and function of science indicators is to follow changes in the scientific enterprise and its components over time, and thereby to reveal strengths and weaknesses as they begin to develop. Such indicators, updated regularly, can provide early warnings of trends that might impair the ability of American science and some aspects of technology to meet the needs of the Nation. Taken together, indicators can make decisionmakers more aware of the interrelatedness of the many variables which describe the Nation's scientific effort. Hence they can assist those who set priorities for the enterprise and allocate resources to it.

While the indicators reported here are, in general, statistical time series, not every time series is an indicator. In order to serve their policy purpose, indicators must measure in some way either the resources allocated to the scientific enterprise or the fulfillment of its goals. Thus there arises the rough distinction between input and output indicators. Input indicators include the human and financial resources that are made available, including the education of research scientists and changes in the institutional structures within which research and development occur.

While some difficulties remain in the defining and obtaining of input indicators, indicators of output present still greater challenges and consequently are less developed. Many of the "outputs" or results of science are the product of other social entities as well, so that in measuring them one is measuring more than the effects of science. In addition, many of the results that science is thought to have are not definite enough to be measured directly. For example, there can be no precise measure of the advance of knowledge. One might decide to count research reports, under the assumption that their distribution over fields and their changes over time provide information about the corresponding distribution and changes in the advance of knowledge. In this situation, one would also want to have additional indicators of the advance of knowledge, to see if they confirmed what had been learned from the counts of research reports. This example reveals the character of many output indicators, namely, that they are quantitative measures standing as surrogates or approximations for something that cannot be directly measured. It also illustrates the value of having a number of indicators to reflect each of the outputs of science.

Outputs include the proximate products of scientific research as well as its social and economic effects. In combination, indicators of these outputs complement each other and enable a picture of the "status and health" of science to emerge. Individually, however, they may be misleading, and even taken together they do not serve their purpose without the application of the experience and sound judgment of the policymakers and others who use them.

Confidence in a particular indicator is strengthened if it can be followed over time and its changes observed in relation to other indicators. These relationships would be much clearer if there were an explicit model available of the research enterprise, both in itself and in relation to the rest of society. Such an ideal model would help to fix the significance of each indicator and would enable the various indicators to be correlated. The models that exist, however, are less than adequate for this purpose. Still, the development of such conceptual formulations of the scientific enterprise will probably be an integral part of later stages in the development of indicators. For the present, one must rely on less formal notions of the cause-effect relationship that holds between input and output indicators, as well as on less definite notions of the exact significance and precise impact of each individual indicator. This again brings out the need for the application of judgment in interpreting these indicators.

Acknowledgments

The National Science Board was aided in the preparation of this report by organizations inside and outside the National Science Foundation. In particular, the Division of Science Resources Studies, National Science Foundation, provided data input through its many publications.

Chapter 1

International Indicators of Science and Technology

International Indicators of Science and Technology

INDICATOR HIGHLIGHTS

- The relative emphasis placed by a country on research and development activities can be approximated by comparing its R&D expenditures to its Gross National Product (GNP). During the middle and late 1960's, and continuing into the early seventies, this ratio generally showed a decline for the United States, the United Kingdom, France, and Canada. The West German ratio peaked in 1971 and now appears to be declining. The U.S.S.R.'s positive growth seems to have leveled off since 1973.[1] Since the late 1960's, Japan has generally shown increases in its R&D/GNP ratio.
- Another comparative measure of a country's R&D effort is the relationship between the number of scientists and engineers (S&E's) and the population. The number of S&E's per 10,000 population in the United States has remained constant since 1972. The 1975 level is 10 percent lower than that of 1969, when this ratio peaked in the United States. Limited data from the other countries studied showed a general increase in this ratio.
- A major difference between the R&D programs of the United States and other countries relates to the distribution of Government funds by function. Among the countries for which data are available, the United States devotes a much higher proportion of Federal R&D funds to defense and space-related activities, especially the former.[2]
- The United States contributes significantly to the world's scientific and technical knowledge base. Non-U.S. authors cited U.S. scientific publications 15 percent more in 1975 than could be expected from the U.S. share of the world's scientific literature—citations to U.S. chemistry, physics, and biomedical research publications were respectively 42 percent, 30 percent, and 26 percent more than could be expected.
- The United States also utilizes other nations' scientific findings and journals. In 1975, 57 percent of the citations appearing in U.S. chemistry publications and 49 percent of those in U.S. physics publications were to foreign publications. Those fields with the greatest percentage of articles appearing in non-U.S. journals in 1975 were mathematics and biomedical research (both 27 percent) and physics and chemistry (both 24 percent).
- Since 1961, U.S. scientists have received 53 percent of the Nobel Prizes in physics, 36 percent in chemistry, and 53 percent in physiology/medicine. This represents 47 laureates or 24 percent more Nobel Prize winners in science than during the 1946-1960 period. While U.S. scientists received all of the Nobel Prizes awarded in 1976, the U.S. share of total prizes has remained at about 50 percent since 1946.
- Although positive, the U.S. patent balance declined almost 47 percent between 1966 and 1975. This was due to the 91 percent increase of foreign-origin patenting, coupled with the leveling off and eventual decline in the number of foreign patents awarded to U.S. citizens. The United States has a favorable but declining patent balance with Canada, the United Kingdom, and five European Economic Community countries, but a negative balance with West Germany and Japan.
- The share of U.S. patents granted to foreign residents has more than doubled in the last

[1] Data regarding the U.S.S.R. should be treated as estimates; limited information and differences in basic definitions make international comparisons involving the U.S.S.R. very difficult. (See the following text for discussion of this point.)

[2] Data for the U.S.S.R. are not available.

15 years, reaching a level of more than 35 percent in 1975. The two countries most active in obtaining U.S. patents are West Germany and Japan. Since 1963, West German inventors have been granted the largest amount of foreign-origin patents, but Japan is fast approaching the West German level. Since 1970, Japanese patenting in the United States has increased more than 100 percent in almost every major industrial category.

- A sample of major U.S. innovations shows those of the United States to be almost entirely based on domestic inventions (93 percent) and highly directed towards producer goods markets (47 percent). Of the countries studied, the United Kingdom has the highest concentration of innovations aimed at producer goods (72 percent), while French innovations are often directed toward the government rather than other markets.

- Since 1960, the United States has maintained an increasingly positive balance of payments associated with the sale of technical know-how (patents, licenses, manufacturing rights, etc.). Royalties and fees associated with direct investment have expanded twice as fast as those from unaffiliated firms from 1966 to 1975. U.S. technology and know-how have been largely transferred to industrialized countries, particularly in Western Europe, with 78 percent of direct investment-related, and 85 percent of unaffiliated purchases, being made in 1975 by developed countries. Likewise, almost all of the foreign know-how purchased by the United States in 1975 came from Western Europe (73 percent) and Canada (22 percent).

- Productivity levels in the United States exceed those of France, West Germany, and the United Kingdom, but U.S. productivity gains between 1960 and 1976 were the smallest of the five countries. Japanese productivity gains were more than five times greater than U.S. increases, although the actual productivity level was still 40 percent below that of the United States in 1976.

- The U.S. trade balance for R&D-intensive manufactured products has been positive and rising since 1960; the 1976 balance was five times that of 1960 and 2½ times the 1970 level. Surpluses from R&D-intensive product groups have had an extremely important role in maintaining an overall favorable U.S. trade balance, and until 1976, have been more than sufficient to cover the increasing deficits from non-R&D-intensive products.

- The primary R&D-intensive exports to Western Europe were largely products of the aircraft and nonelectrical machinery industries, while chiefly nonelectrical machinery and chemical products were exported to developing countries, and electrical and nonelectrical machinery to Canada. The negative trade balance in R&D-intensive products with Japan was due mainly to U.S. imports of electrical machinery and to a lesser degree to imports of professional and scientific instruments and nonelectrical machinery.

The interrelatedness of the world is a prevalent theme of today. This is especially true with regard to science, which by its very nature is not limited by political boundaries, but rather is transnational in character. The internationalism of science is based on the fact that research findings have universal validity. Science is an accumulative effort and the body of scientific knowledge has been built over time with the contributions of researchers and thinkers from all nations.

Technology, on the other hand, may be less universal in nature, as has been pointed out by the recent call for intermediate or appropriate technologies for particular environments,

especially developing countries.[3] Such technologies are labor-intensive, efficient on small scales, easily serviceable, and use locally available materials. However, even though they may differ in their applicability or usefulness—depending on many factors such as culture, levels of economic development, and market structure—technologies often produce global impacts (i.e., nuclear reactors and weapons, communications satellites, oral contraceptives, and jet engines). The desire to find better, faster or more efficient ways of doing things is not limited to any particular country or society. Additionally, technologies cross national boundaries in many forms including foreign trade, exchange or assistance programs, and the sale of technical knowledge.

This chapter attempts to view U.S. science and technology as they interface and interact with international scientific and technological endeavors. Indicators are presented to show the level of investment in research and development in various countries in terms of money and manpower. Examination is also made of performance measures. The extent and significance of scientific research is reflected here by participation in multinational scientific meetings and the proliferation of scientific literature and cross-country citations. International prizes point to the prestige of science. Indicators of technological activity include, among others, invention and innovation patterns, international transactions in technical know-how, and trade balances in R&D-intensive products.

International indicators of science and technology are faced with problems of data availability and reliability, and cross-country differences in definitions and concepts, methodologies, and statistical reporting procedures.[4] For these reasons as well as the fact that not every country allocates the same importance or priority to research and development, the emphasis of this chapter is more on understanding where the United States fits within the framework of trends in international science and technology than on cross-country comparisons in general.

RESOURCES FOR R&D

Most of the research and development performed throughout the world has generally been attributed to the scientific and technological endeavors of seven nations. Presented here are comparisons of the levels of financial and manpower resources invested in research and development by these nations and a brief examination of the major sources of support and general areas of R&D activity (e.g., defense, space, and health). It should be noted that expenditures reported for the United States and the Soviet Union are for the performance of R&D alone, while those for other countries include their associated capital expenditures.

Expenditures for R&D

Direct international comparisons of the levels of effort devoted to research and development are severely hampered by constantly fluctuating exchange rates among international currencies and differences in the composition and relative costs of manpower and capital inputs into the R&D programs of different nations. The indicator used most often to circumvent these difficulties is the ratio of gross national expenditures for research and development (GERD) to the Gross National Product (GNP). This provides one measure of the fraction of a country's total economic output that is devoted to the performance of research and development and therefore is an indication of the level of a nation's R&D effort.

The Organisation of Economic Co-operation and Development has developed a classification scheme for countries according to their absolute and relative amounts of resources devoted to

[3] See for example, E.F. Schumacher, *Small is Beautiful: Economics as if People Mattered* (New York: Harper and Row, 1973); Nicolas Jequire, ed., *Appropriate Technology: Problems and Promises* (Paris: Organisation of Economic Co-operation and Development, 1976); "Proposal for a Program in Appropriate Technology," transmitted by the Agency for International Development to the Committee on International Relations, U.S. House of Representatives, 94th Congress, 2d Session, July 27, 1976. See also Richard S. Eckaus, *Appropriate Technologies for Developing Countries*, (Washington, D.C.: National Academy of Sciences, 1977). This report points out that criteria and goals for technological choices are often conflicting or inconsistent; that present understanding of both the characteristics of technology and the methods and consequences of technology transfer is meager; and thus it is difficult at best to identify what an "appropriate technology" might be.

[4] The Organisation of Economic Co-operation and Development has attempted to deal with the problem of international R&D statistics. However, many of the above-mentioned problems persist.

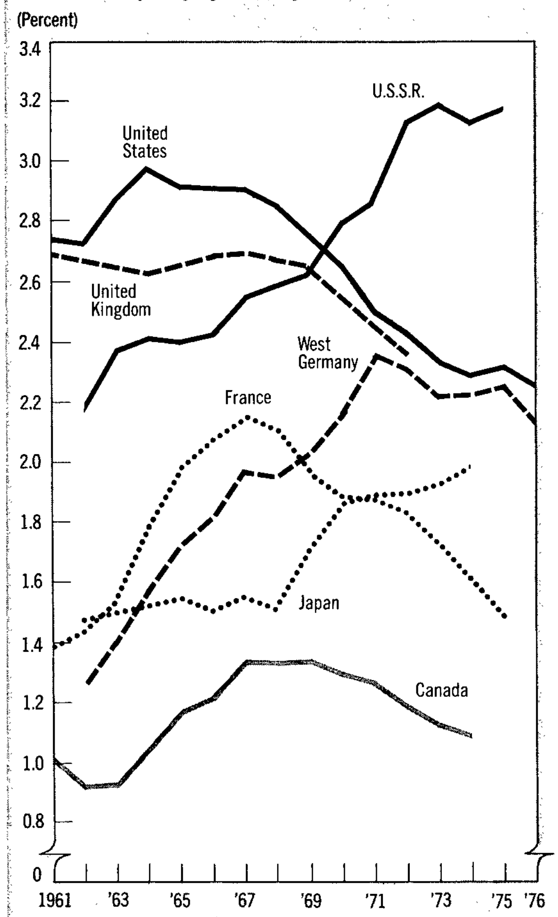
R&D.[5] Those countries which expend sufficiently large funds on R&D to be able to undertake a wide range of projects and which are highly "R&D-intensive" (i.e., those which have a GERD/GNP ratio of over 1.6 percent) include the United States, the United Kingdom, West Germany, France, Japan, and the Soviet Union.[6] Canada falls into the group which devotes moderately large sums to R&D (0.6 - 1.5 GERD/GNP), thus permitting major efforts in one or two areas, but with a smaller share of national resources expended on research. The majority of the developing countries allocate small amounts of resources to R&D in both absolute and relative terms (less than 0.3 percent of GNP).[7]

During the middle and late 1960's, the level of R&D funding in the United States, the United Kingdom, France, and Canada began a decline relative to the GNP of these countries. As can be seen in Figure 1-1, available data for the United Kingdom, France, and Canada do not as yet show signs of overcoming this decline. For the United States, 1975 saw a slight increase in the ratio—but estimates for 1976 show a large decrease to 2.25 percent, the lowest of the period.[8]

In the United States, the United Kingdom, and France, the R&D expenditure per GNP decreases over the past several years reflect a diminished share of GNP devoted to the performance of R&D rather than a decrease in absolute levels of funding. However, absolute reductions were experienced in the Government space R&D budget in the United States and in defense and energy R&D funds in France (see Appendix Table 1-3). Canada, while increasing the level of R&D funding, has enjoyed large increases in GNP in recent years, thus accounting for decreases in the ratio of R&D expenditures to GNP.

1-1

National Expenditures for performance of R&D[1] as a percent of Gross National Product (GNP) by country, 1961-76



[1] Gross expenditures for performance of R&D including associated capital expenditures (except for the United States and the U.S.S.R. where total capital expenditure data are not available).

NOTE: Estimates are shown for 1974, 1975 and 1976. United Kingdom figures for 1968-69 are shown as 1968, 1969-70 as 1969, and 1972-73 as 1972.

REFERENCE: Appendix Table 1-1.

During the decade 1962-72, both Japan and West Germany recorded substantial growth in the proportion of their GNP directed toward R&D. Between 1972 and 1974, Japan continued to increase its R&D proportion, while West Germany showed signs of entering a leveling-off period and an eventual decline in 1976. Underlying their growth during this period were continuous large increases in R&D funding from both industry and government with a smaller

[5] Further discussion of individual country performance within each of these groups appears in "Trends in R&D Between 1971 and 1973 in OECD Countries," *Science Resources Newsletter*, No. 1, OECD, September 1976.

[6] Although OECD classifies France in this group, in 1975 the French GERD/GNP ratio dropped to 1.48. The U.S.S.R. is not classified by OECD but is mentioned here because it would fit into this grouping.

[7] "Contribution of R&D Statistics to the Understanding of Structural Differences Between Countries" in *Federal Policy, Plans, and Organization for Science and Technology, Part II*, U.S. Congress, House Committee on Science and Astronautics, 93d Congress, 2d Session, 1974, p. 27.

[8] Estimated from National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), p. 28, and *Commerce News*, March 21, 1977.

proportion of the total earmarked for defense-related R&D. Total R&D expenditures by Japan increased at an average annual rate of nearly 19 percent between 1962 and 1972, and those of West Germany at 16 percent, as compared to a 6 percent rate of growth in R&D expenditures in the United States. Between 1972 and 1974, however, total R&D expenditures increased about 50 percent in Japan, but only 15 percent in West Germany and 14 percent in the United States. From 1975 to 1976, total R&D expenditures increased by only 3 percent in West Germany and 8 percent in the United States. Unlike the experience of the United States and France, R&D funds provided by the governments of Japan and West Germany grew more rapidly until 1973 than corresponding industry funds. Historically, industry has provided over 60 percent and 50 percent of national R&D funds, respectively, in the latter two countries.[9] The government R&D funds in both Japan and West Germany are concentrated on the advancement of knowledge and, to a lesser extent, on general economic growth and energy production. Little emphasis is given to military, space, or health research and development.[10]

Differences in Soviet R&D definitions and GNP accounting make international comparisons involving the Soviet Union more hazardous than with other countries. For instance, expenditures for space hardware or the development of industrial prototypes are not generally considered as R&D allocations in the Soviet Union and are not included in expenditures on science. These factors would tend to deflate Soviet R&D figures relative to those of other nations, while certain other discrepancies in R&D accounting definitions would tend to inflate Soviet figures; there is good evidence that Soviet budget expenditures on science include graduate training costs, and the wages of a large number of support personnel employed at R&D institutions, as well as expenditures for all social science research including general planning and economic forecasting. Although it is difficult to determine precisely how the Soviet statistics compare, it is thought that they are significantly over-estimated relative to U.S. data.[11]

R&D personnel

Figure 1-2 shows the number of R&D scientists and engineers per 10,000 population between 1965 and 1975 for the seven nations mentioned earlier. This indicator provides yet another comparison of the extent of a country's national R&D effort. Since there are many variations in the sophistication level and productivity of R&D inputs of nations, this indicator should be viewed only as an approximate measure of the depth and direction of a country's R&D effort.

As can be seen from the figure, the United States experienced a 9 percent decline in the number of scientists and engineers engaged in R&D per 10,000 from 1969 to 1971, which then remained at a nearly constant level through 1975.[12] The number of R&D-performing scientists and engineers in each of the remaining countries rose at a faster rate than their respective populations. Not only did the proportion of R&D scientists and engineers per 10,000 population in the United States decline during this period, but the actual number fell from 558,200 in 1969 to 521,900 in 1972. Recent data, however, show an increase of 8,400 between 1972 and 1975.

Data for the U.S.S.R., though more difficult to assess for accuracy, imply that the number of scientists and engineers engaged in R&D increased by over 200,000 during 1969-73, a period of U.S. decline (see Appendix Table 1-2). However, since 1973 the Soviet ratio of scientists and engineers to total population seems to have leveled off.[13]

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[9] Organisation for Economic Co-operation and Development, *International Survey of Resources Devoted to R&D by OECD Member Countries*, for 1963, 1967, 1969, 1971, and 1973.

[10] Information on the distribution of government R&D expenditures among these and other areas is presented in a later section of this chapter.

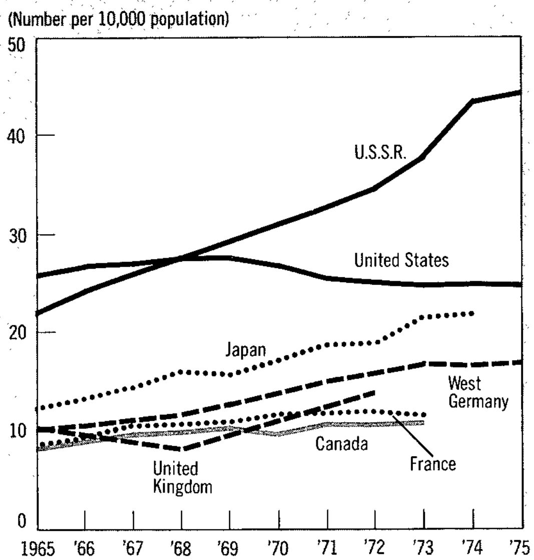
[11] Robert W. Campbell, "Reference Source on U.S.S.R. R&D Statistics," Indiana University, June 1976, pp. 2-18 (A study specifically conducted for this report).

[12] The U.S. decline is due in large part to decreases in the employment of scientists and engineers in space and defense-related R&D. See the "Industrial R&D and Innovation" chapter of this report for further details.

[13] There are numerous problems involved in comparing U.S. and Soviet scientific manpower statistics, but attempts have been made here to present figures representing as closely as possible U.S. definitions of full-time-equivalent scientists and engineers. Questions as to the quality of training in either country are not addressed here. However, for some discussion of comparability of educational training and degrees awarded see Roger K. Talley, Soviet Professional Scientific and Technical Manpower (Washington D.C.: Defense Intelligence Agency, 1976), pp. 9-36.

1-2

Scientists and engineers[1] engaged in R&D per 10,000 population by country, 1965-75



[1] Includes all scientists and engineers on a full-time-equivalent basis (except Japan whose data include persons primarily employed in R&D and the United Kingdom whose data include only the government and industry sectors).

NOTE: Estimates are shown for 1974 and 1975.

REFERENCE: Appendix Table 1-2.

In Japan, the United States, and the Soviet Union the R&D science and engineering manpower ratio generally paralleled the trends in the respective R&D/GNP ratios mentioned earlier. In Canada and West Germany the R&D manpower ratio continued to increase even when the R&D/GNP ratio decreased.

Government-funded R&D

Governments generally provide funds for R&D in areas which are national in scope or are of particular interest to the government and their citizens but which are not supported by the private sector for reasons of high risk or insufficient incentive. Thus support is provided for basic research, national defense, space exploration, public health, and economic development. How a government distributes its funds among the R&D programs in these and other areas is a good indication of national priorities.

Attempts have been made by the Organisation for Economic Co-operation and Development (OECD) to determine how its member countries are allocating R&D funds among various objectives or priorities. Certain limitations and caveats should be kept in mind in reading the following section which deals with the OECD effort to categorize national government R&D funds. The data may not be as internationally comparable as other OECD data because the survey is still in the early stages of development, there is uneven experience among nations in collecting such data, and a more uniform approach and agreement on some technical problems is still needed. An initial attempt was made to categorize R&D funds by objective for the years 1961-1972.[14] OECD then made refinements in the classification methodology in line with the *Proposed Standard Practice for Surveys of Research and Experimental Development* (Frascati Manual) as well as guidelines developed by the European Economic Community (EEC) and the Scandinavian Council for Applied Research (Nordforsk). Data for more recent years were collected in the International Survey of the Resources Devoted to R&D in 1973, and released in a 1977 report.[15] A strict match between the current and former OECD detailed classifications does not exist but a close correspondence on an aggregated level does permit general observations of national priorities and thrusts.[16] The results of the studies should be considered experimental or preliminary in nature and may differ slightly from other OECD survey data or from data available in national publications. Finally, the distribution pattern of R&D expenditures discussed here is limited to funding by governments because data on R&D funding by the private sector categorized by similar objectives are not available, even for the United States.

Government expenditures for R&D are classified into the following categories:

> *National Defense,* encompassing all R&D directly related to miltary purposes, including space and nuclear energy activities of a military character;

[14] Organisation for Economic Co-operation and Development, *Changing Priorities for Government R&D* (Paris: OECD, 1975).

[15] Organisation for Economic Co-operation and Development, *International Statistical Year—1973: The Objectives of Government R&D Funding, 1970-76 Vol. 2(B)* (Paris: OECD, 1977).

[16] *Ibid.*, p. 30.

Space, including all civilian space R&D such as manned space flight programs and scientific investigations in space;

Energy Production, consisting of all R&D activities aimed at the supply, production, conservation, and distribution of all forms of energy except as means of propulsion for vehicles and rockets;

Economic Development, which covers R&D in a wide range of fields including: agriculture, forestry, and fisheries; mining and manufacturing; transportation, telecommunications (including satellite communications), construction, urban and rural planning, and utilities;

Health, encompassing R&D in all of the medical sciences, and in health service management directed toward the protection and improvement of human health;

Community Services, which includes R&D for such purposes as environmental protection, educational methods, social and development services, fire and other disaster prevention, planning and statistics, recreation and culture, law and order; and

Advancement of Knowledge, contains R&D of a general nature or spanning several fields which cannot be attributed to specific objectives; it consists of R&D expenditures of science councils, private nonprofit institutes, and general university funds.

As can be seen in Figure 1-3, the United States differs significantly from other major R&D-performing nations in that a larger percentage of its Government R&D funds is allocated to defense and space programs.[17] In 1974-75, the United States allocated almost 51 percent of its Government R&D funding to defense-related programs and an additional 13 percent to space R&D. The United Kingdom spent 47 percent in the area of defense in 1974-75 and 2 percent on space, while France spent 30 percent on national defense in 1975 and 6 percent on space—these countries were the closest to the United States in those categories. The United States, on a percentage basis, allocated a comparatively small share for the advancement of knowledge (4 percent in 1974-75)[18] while government-funded R&D in other countries was heavily concentrated in this area—particularly Japan (55 percent in 1974-75) and West Germany (51 percent in 1975). It should be emphasized, however, that for the United States, general university funds are not included in this category and that since World War II until recently, the governments of West Germany and Japan have not funded any significant amounts of defense-related R&D, and only negligible amounts of space-related activities. Canada (14 percent) and West Germany (11 percent) allotted more national government funds to energy than did the other countries, who allocated on an average 6 to 9 percent of their budget to this area.

There were some similarities in the way the various governments changed their R&D funding patterns during the 1961-75 period. For instance, in each country the proportion of total R&D expenditures allocated to defense-related activities declined. The trend shown during this decade implies a definite shifting from military R&D applications to areas of domestic concern and the advancement of knowledge, even though the absolute magnitude of R&D expenditures for national defense continued to increase in all countries during this period except for Canada and France, whose defense expenditures decreased in 1970-71 and then rose again in 1974-75.

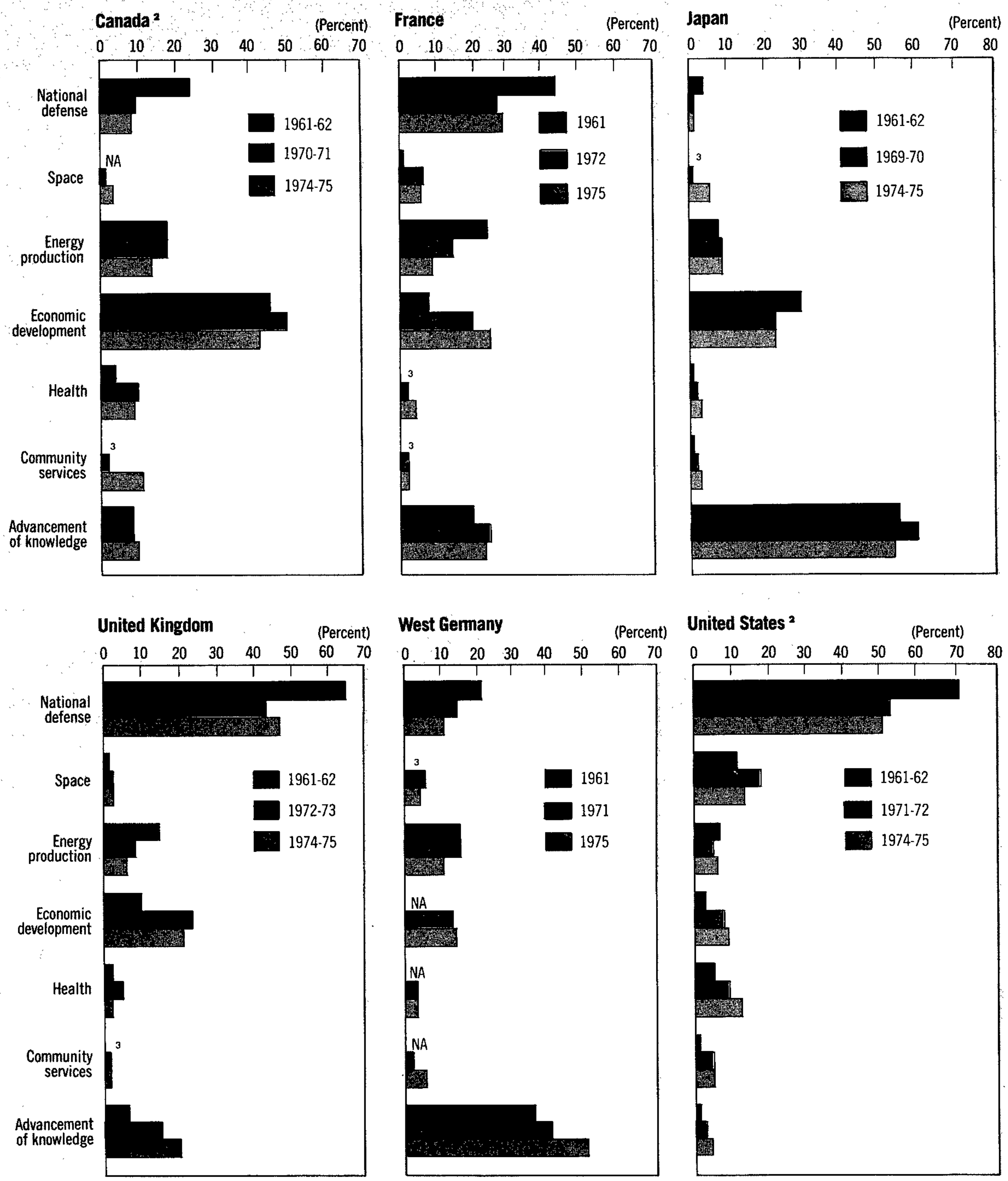
In each country the percentage of funds devoted to the advancement of knowledge and economic development increased except for Japan, whose share remained at the same high level. The greatest change over the period in Canadian funding occurred in the areas of defense and health; from 1961-62 to 1974-75, the share of government R&D expenditures devoted to defense decreased from 24 percent to 8 percent, while those devoted to health increased from 4 percent to 9 percent. France decreased its share of funds devoted to energy over the period from 25 percent to 9 percent while the share of funds devoted to economic development increased from 8 percent to 26 percent. In West Germany, the share of funds devoted to the advancement of knowledge increased dramatically from 37 to 51 percent.

[17] Distribution data are not available for the U.S.S.R.; it is a controversial and as yet unresolved issue as to whether Soviet military R&D is included in reported total R&D expenditures.

[18] For current information on the distribution of U.S. Government expenditures for R&D, see the chapter in this report entitled "Resources for R&D."

1-3

Estimated distribution of Government R&D expenditures among selected areas[1] by country, 1961-75



[1] Function categories are not the same as those of Appendix Table 2-11, e.g., "Advancement of knowledge" does not equal "Science and technology base."

[2] Advancement of knowledge does not include general university funds.

[3] Less than 0.5 percent.

NA = not available

REFERENCE: Appendix Table 1-3.

THE INTERNATIONAL CHARACTER OF SCIENCE

The international community of scientists has been fostered by international meetings and travel, joint research efforts, informal communication between scientists, and the publication of research findings in widely circulated journals. In addition, many formal arrangements have been established to ensure international scientific cooperation and the exchange of data, among them bilateral agreements, multilateral arrangements such as the specialized scientific agencies of the United Nations, and an array of nongovernmental associations for the advancement of science and exchange of scientific information, such as those encompassed in the International Council of Scientific Unions (ICSU).

This section presents indicators which attempt to measure the extent, influence, and nature of international science. Several indicators are provided to describe the scientific and technical information flow between the United States and the rest of the world, including measures of the U.S. share of the world literature in various fields, who publishes in U.S. journals and who cites U.S. publications, as well as international publishing, referencing and cooperative authorship by U.S. authors. Scientific interaction may be inferred from the degree of participation in international scientific meetings. The distribution of international prizes is also offered as an indication of significant advancement in several fields.

Scientific literature

Research reports published in scientific and technical journals are one of the more direct outputs of scientific effort.[19] Such reports add to the body of scientific knowledge and may stimulate further research. The findings of the research, in addition, may be used in a variety of practical applications, many of which are unanticipated at the time the research is done. Although the reports may vary considerably in their theoretical and practical importance, the critical review which usually precedes publication helps to ensure that the reports have some degree of scientific or technical significance.

Indicators based on research reports, however, have several limitations when used for international comparisons, providing good reasons for caution in use and interpretation. For example, the results of literature analysis depend heavily on the set of journals selected for examination.[20] National customs or restraints on the space available per publication can affect these results reducing the space available for references; however, the impact of this cutback on international citing is unknown. Other factors that affect the publication of scientific and technical literature are the availability of funding for preparing and printing the report, journal refereeing and publishing policies and the like—all of which undoubtedly vary from country-to-country and across different fields.

The indicators provided in this section help describe the role of the United States in the world of science and technology, and the extent to which U.S. scientists and engineers depend on the published literature and publication facilities that other countries make available to them. More specifically, there are indicators to estimate the U.S. share of the world literature of science and technology; show who publishes in U.S. journals; indicate who cites U.S. publications; illustrate the international publishing by U.S. authors and their referencing of other nations' literature; and measure the international cooperative authorship of U.S. publications.

Recent information on the number of U.S. scientific and technical publications as a share of

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[19] For discussions of publications as measures of the output of science, see: G. Nigel Gilbert and Steve Woolgas, "The Quantitative Study of Science: An Examination of the Literature," *Science Studies* Vol. 4 (1974), pp. 279-294; Henry Menard, *Science: Growth and Change* (Cambridge: Harvard University Press, 1971); Derek J. de Solla Price, *Little Science, Big Science* (New York: Columbia University Press, 1963); and Francis Narin, et al., *Evaluative Bibliometrics: The Use of Publication and Citation Analysis in the Evaluation of Scientific Activity* (Cherry Hill, N.J.: Computer Horizons, Inc., 1976).

[20] Recent investigations conducted in the preparation of this report indicate that the 2,400 journals of the *Science Citation Index* published by the Institute of Scientific Information may not reflect for even the major nations the exact distribution of their overall literature. The problem is more severe for the U.S.S.R. and Japan. In the treatment of *S.C.I.* data here, emphasis is placed on U.S. literature.

all world literature shows considerable stability. As Table 1-4 indicates below, almost 40 percent of the world's scientific and technical journal literature is accounted for by U.S. authors.[21] For psychology, the U.S. proportion is about 75 percent, whereas U.S. chemistry and physics publications are only 22 and 32 percent, respectively.

1-4. U.S. share of the world publications[1] from a large sample of influential journals, 1973-75

Field	1973	1974	1975
All fields[2]	39	39	38
Clinical medicine	43	42	43
Biomedical research	39	38	39
Biology	46	46	44
Chemistry	23	22	22
Physics	33	33	32
Earth and space sciences	47	47	45
Engineering and technology	42	42	41
Psychology	76	75	75
Mathematics	48	46	44

[1] As a percentage of 276,000 articles, notes and reviews from the 2,400 influential journals of the *Science Citation Index* Corporate Tapes, 1975, and earlier years.
[2] See Appendix Table 1-5 for the subfields included in these fields.
SOURCE: Computer Horizons, Inc., unpublished data.

Countries of authors writing in U.S. journals. Journals published in the United States serve as a vehicle for the dissemination of the results of world scientific and technology efforts. Other countries' journals also serve this purpose, although among the seven major R&D-producing nations, only the United Kingdom and West Germany exceed the United States in the proportion of their journals' articles which originate outside the country.[22]

Although U.S. authors provided the preponderance of publications appearing in U.S. journals (see Figure 1-5), this proportion varies considerably by field, from a high of 84 percent in psychology (which we have already seen as highly dominated by U.S. authors), to the much lower shares of 55 percent for chemistry and 66 percent for physics. In these two fields, not only are there proportionately more authors writing in U.S. journals from the other major R&D nations, but considerably more from the smaller nations as a group as well.

When non-U.S. scientific and technical research results are published in U.S. journals, the findings are readily useable by the U.S. scientific community, with little delay. This is advantageous for U.S. scientists, while at the same time it provides a forum for significant research results. In four fields,[23] substantially more publications by non-U.S. authors appear in U.S. journals than U.S. literature in non-U.S. journals.

Influence of U.S. literature. The U.S. scientific and technical literature is widely cited in the publications of all countries. Table 1-6 shows the distribution of the citations (i.e., references) to U.S. literature from the 1975 world literature, nearly 50 percent of all citations. Chemistry and physics again are the U.S. fields which are most used by non-U.S. scientists, while psychology citations to U.S. literature come largely from the United States itself. The United Kingdom is the second largest contributor of citations to U.S. literature in every field (See Appendix Table 1-6).[24]

[21] The field of science for each publication was derived from the field or fields to which its journal had been assigned. The nationality of an author is based on his organization or institution. When more than one country is involved in multiple authorship, the publication is assigned fractionally to the countries involved.

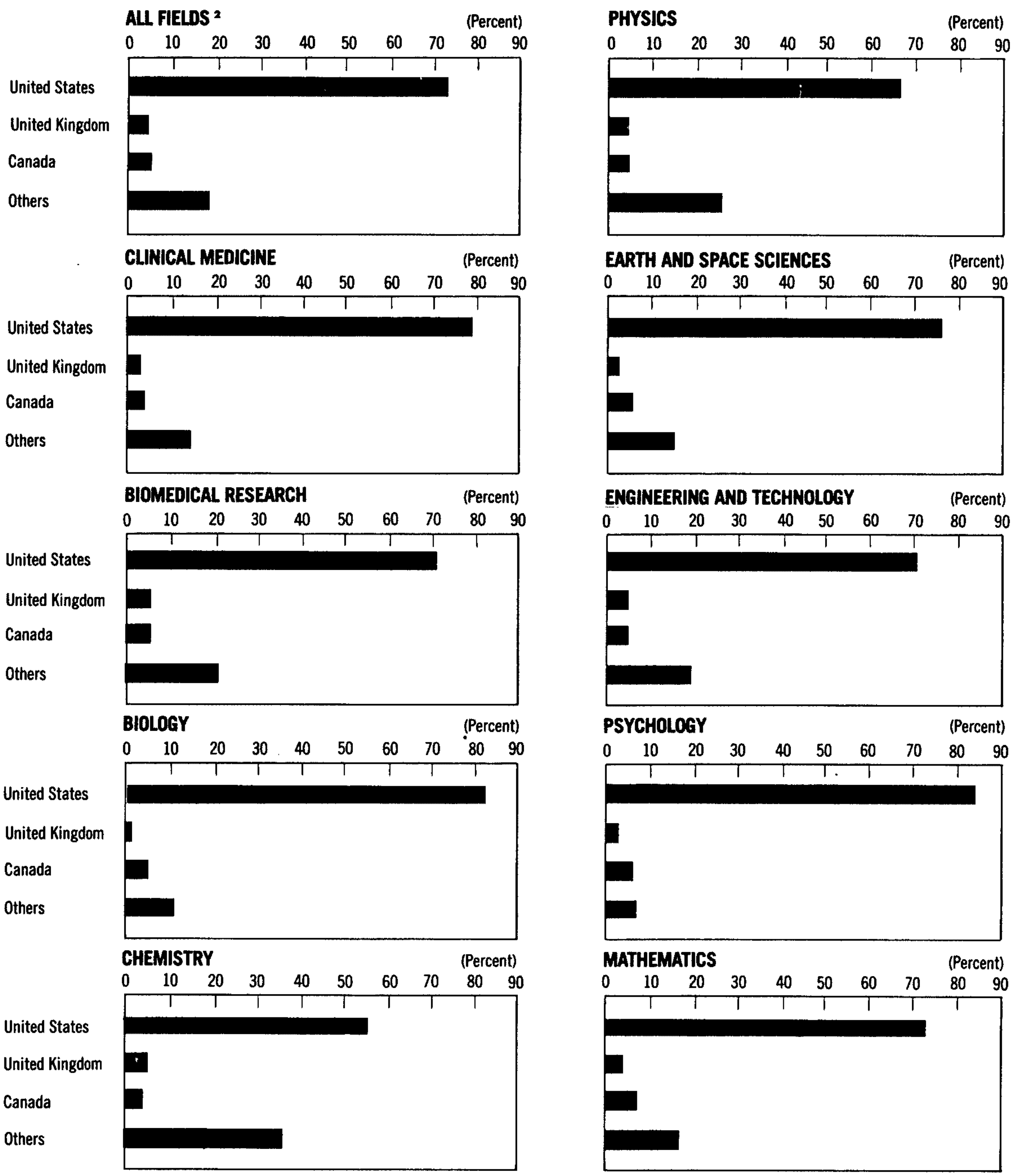
[22] Computer Horizons, Inc., unpublished data.

[23] Chemistry, engineering and technology, clinical medicine, and physics.

[24] Although the U.S.S.R. contributed the smallest number of citations to U.S. literature from these seven countries, this may result from special problems of that country's scientific information system as described in V.V. Nalimov and Z.M. Mul'chenko, *Naukometria*, (Moscow: Nauka, 1969), and Yakov M. Rabin, 'Naukovedenie': The Study of Scientific Research in the Soviet Union," *Minerva*, Vol. 14 (Spring 1976), pp. 61-78.

1-5

Distribution of publications [1] in U. S. journals by field and country of author, 1975



[1] Includes 117,000 articles, notes and reviews from the influential U. S. journals in the *Science Citation Index* Corporate Tape, 1975. Corporate tape data use throughout this section include only those publications carrying the author's place of employment or affiliation.

[2] See Appendix Table 1-5 for the subfields included in these fields.

REFERENCE: Appendix Table 1-4.

1-6. Percent of all citations found in publications[1] of other countries that are to U.S. publications, by field, 1975

Field[2]	Percent
All fields	52
Chemistry	65
Physics	59
Biomedical research	52
Engineering and technology	52
Clinical medicine	49
Biology	48
Mathematics	48
Earth and space sciences	43
Psychology	28

[1] Based on a study of over 276,000 articles, notes and reviews from the 2,400 influential journals of the *Science Citation Index* Corporate Tape, 1975.

[2] See Appendix Table 1-5 for the subfields included in these fields.

REFERENCE: Appendix Table 1-6.

That the United States should have large fractions of the citations to the world literature is in part a consequence of the large share of the world literature it produces (see Table 1-4). "Citation ratios" are one way to correct for this factor. Citation ratios are based on the belief that the most significant or influential literature will be more frequently cited than the routine literature. In support of this assumption are a number of studies which demonstrate high correlation between citations to an author's work and other measures of scientific importance, such as judgments of researchers in the field.[25]

However, some articles may fail to be noticed because scientists do not have access to them, although this characteristic of the availability of a nation's scientific literature is itself an important aspect of the internationalism of science. Articles may be heavily cited only for the criticisms they provoke, or because they deal with minor improvements in methodology. Authors in some countries may cite only a few outstanding references for reasons such as journal space limitations, while similar scientists in other countries may give more complete citations. The particular choice of a sample of journals to be examined can have an effect on international comparisons if countries do not have appropriate representation in the sample.

The citation ratios presented in Table 1-7 are based on citations from the world's literature to U.S. literature, adjusted to account for the share of publications associated with the United States in each field.

As is the case in all countries, self-citing is higher than citing from other nations.[26] In Table 1-7, the citation ratios of U.S. authors toward their own country's scientific and technical literature is in the range of 25 to 95 percent greater than expected (ratios of 1.25 and 1.95), indicating a greater or lesser use of U.S. literature by U.S. authors in different fields. The most influential fields of U.S. literature as measured by this indicator of world literature are seen by non-U.S. authors to be chemistry (1.42) and physics (1.30), followed closely by biomedical research (1.26). The English-language obstacle to the citing of U.S. publications appears to be substantial in the three fields of biomedical research, chemistry, and engineering and technology; only small differences occur in psychology and clinical medicine when the language barrier is removed.[27]

U.S. publication in the world's journals. Although U.S. authors publish largely in U.S. journals (see Figure 1-8), there is considerable variation across fields, from 89 percent in psychology and 88 percent in engineering and

[25] See "Citation Analysis: A New Tool for Science Administrators," *Science*, Vol. 188 (1975), pp. 429-432; Jonathan R. Cole and Stephen Cole, *Social Stratification in Science* (Chicago: University of Chicago Press, 1973); Eugene Garfield, "Citation Analysis as a Tool in Journal Evaluation," *Science*, Vol. 178 (1972), pp. 471-478; J. Margolis, "Citation Indexing and Evaluation of Scientific Papers," *Science*, Vol. 155 (1967), pp. 1213-1219; C. Roger Myers, "Journal Citations and Scientific Eminence in Contemporary Psychology," *American Psychologist*, Vol. 25 (1970) pp. 1041-1048; and S. M. Lawani, "Citation Analysis and the Quality of Scientific Productivity," *Bioscience* Vol. 27 (January, 1977), pp. 26-34.

[26] Self-citing as used here means an author citing publications by scientists and engineers from his own country, not citing just his own work.

[27] By contrasting the citation ratios of Canada and the United Kingdom combined, with the other non-U.S. countries as a group, estimates of the English-language obstacle can be made.

1-7. Citation ratios[1] for U.S. publications[2] by the country of citing authors and field, 1975

Field[3]	World publications citing U.S. publications	U.S. publications citing U.S. publications (self-citing)	Non-U.S. publications citing U.S. publications: Total	United Kingdom & Canada	Other Non-U.S. Nations
All fields	1.30	1.51	1.15	1.24	1.12
Clinical medicine	1.31	1.48	1.17	1.20	1.15
Biomedical research	1.35	1.46	1.26	1.30	1.06
Biology	1.13	1.36	.96	1.01	.93
Chemistry	1.57	1.95	1.42	1.61	1.37
Physics	1.41	1.60	1.30	1.42	1.27
Earth and space sciences	1.28	1.40	1.15	1.22	1.12
Engineering and technology	1.17	1.47	.99	1.15	.93
Psychology	1.02	1.05	.96	.96	.95
Mathematics	1.18	1.29	1.09	1.18	1.05

[1] Calculated as follows: The U.S. share of the world's 1975 chemistry *citations* is 34.44 percent and its share of the world's 1975 chemistry *publications* is 21.97 percent. The world-to-U.S. citation ratio is .3444 ÷ .2197, or 1.57. A citation ratio of 1.00 reflects no over- or under-citing of a nation's scientific literature, while a higher ratio indicates a greater influence than would have been expected from the number of a country's publications alone.

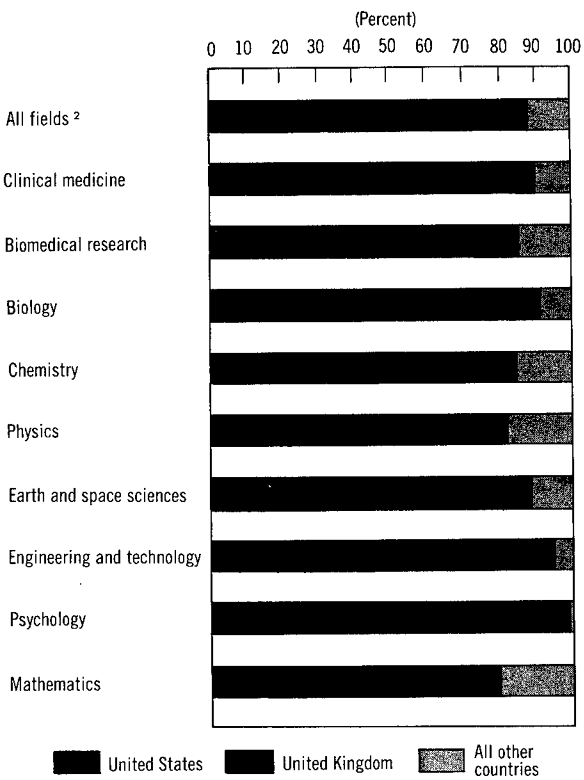
[2] Based on over 276,000 articles, notes and reviews from the 2,400 influential journals of the *Science Citation Index* Corporate Tapes, 1975.

[3] See Appendix Table 1-5 for the subfields included in these fields.

SOURCE: Computer Horizons, Inc., calculated from unpublished data.

1-8

Percent distribution of publications [1] by U. S. authors, by country of journal and field, 1975



[1] Based on 106,000 articles, notes and reviews by U. S. authors in the 24,000 influential journals of the *Science Citation Index* Corporate Tape, 1975.
[2] See Appendix Table 1-5 for the subfields included in these fields.
REFERENCE: Appendix Table 1-7.

technology, to only 73 percent in mathematics and in biomedical research. The United Kingdom is the next most common country of publication for U.S. scientific and technical literature, particularly in biomedical research.

The influence of other nations on U.S. scientific and technical literature. U.S. scientists and engineers draw rather widely from world science, as evidenced by their citations (Table 1-9). U.S. chemistry and physics are, by this measure, more involved in international science, while the U.S. psychology and clinical medicine literatures have the lowest use of non-U.S. publications. The language barrier described above undoubtedly prevents more use of Soviet literature by U.S. scientists and engineers while the greater share of Japanese journals published in English may be responsible for bringing it to the usage level of the French and West German literature.

1-9. Percent of all citations found in U.S. publications[1] that are to publications of other countries, by field, 1975

Field[2]	Percent
All fields	42
Chemistry	57
Physics	49
Biomedical research	43
Mathematics	43
Biology	40
Engineering and technology	40
Earth and space sciences	37
Clinical medicine	37
Psychology	22

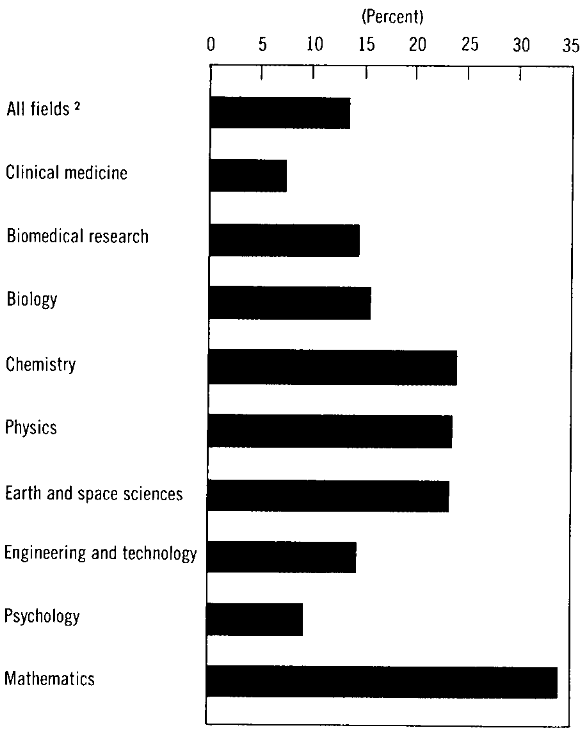
[1] Based on 106,000 articles, notes and reviews written by U.S. authors in the 2,400 influential journals of the *Science Citation Index* Corporate Tape, 1975.
[2] See Appendix Table 1-5 for the subfields included in these fields.
REFERENCE: Appendix Table 1-8.

International cooperation of U.S. authors. Because collaboration on research projects is an increasing form of organization for R&D, particularly where long-term research agenda are being pursued, much scientific and technical literature is produced by more than one author. When these collaborators are located in the same institution or organization, joint writing of papers is facilitated. It is much less common for such cooperative work to proceed at different places, let alone in different countries. Figure 1-10 provides a measure of the international cooperation of U.S. authors, where "cooperative authorship" is defined as existing not simply when there is more than one author, but rather when authors are known to work either in different organizations or in different countries.[28]

[28] It is to be noted that the percents shown in Figure 1-10 do *not* reflect the proportion of articles with more than one author, but rather the proportion of cooperatively authored U.S. publications whose authors were from more than one organization.

1-10

International cooperative authorship of U. S. authors as a percent of all U. S. cooperative authorship by field, 1973 [1]



[1] Based on 36,000 cooperatively authored U. S. publications in the *Science Citation Index* Corporate Tape, 1973.
[2] See Appendix Table 1-5 for the subfields included in these fields.
REFERENCE: Appendix Tables 1-7 and 1-10.

Nearly 35 percent of the cooperatively authored U.S. mathematical publications were across national boundaries, compared to 8 percent in clinical medicine and 9 percent in psychology. Chemistry, physics, and the earth and space sciences have almost identical international cooperative authorship rates—just under 25 percent.

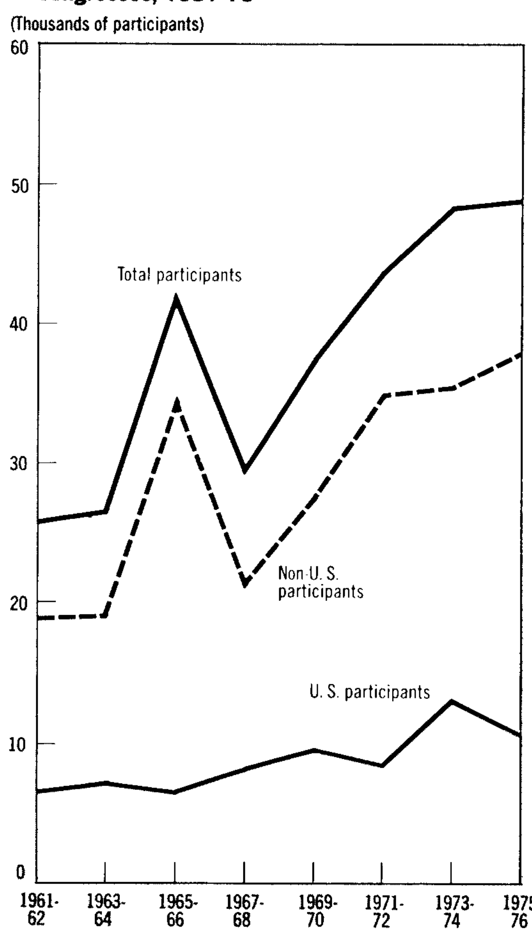
Participation in international congresses

The participation of scientists in international meetings is an important method for the cross-fertilization of ideas and exchange of information. Many contacts made at these meetings later turn into working relationships or sources of communication about new developments in science in other countries. Wide fluctuations exist in participation from year to year depending on such factors as the number and location of meetings[29] and the amount of funds available for travel. Figure 1-11 shows the participation in international congresses of those organizations constituting the International Council of Scientific Unions in recent years. As can be seen, foreign participation has grown rapidly from

[29] For instance, non-U.S. participation experienced a dramatic increase in 1966, a year in which a number of large congresses were held overseas and virtually no major meetings took place in the United States. Many congresses are on a 3 or 4 year cycle. Peaks in attendance patterns also reflect the larger number of congresses held in certain years.

1-11

Participation in international scientific congresses, 1961-76



REFERENCE: Appendix Table 1-11.

1961-62 to 1975-76 while U.S. participation has increased at a more moderate rate and even experienced a 17 percent drop from 1973-74 to 1975-76. Over the fifteen year period, the number of U.S. participants attending international meetings increased by 63 percent while the number of non-U.S. participants almost doubled, an encouraging sign for worldwide scientific interaction.

International prizes

International prizes for excellence in scientific research are viewed by some as measures of the output of a nation's scientific endeavors, while others argue that they are not directly related to national research efforts. They are, however, useful as an indication of the prestige of science and may act to highlight and map singular developments which significantly advance the state of the art in a particular field.

By far the most widely recognized international scientific honor is the Nobel Prize, which is awarded annually in the fields of physics, chemistry, and physiology/medicine (as well as literature, economics and peace). As with any such award, the Nobel Prize has been subject to some criticisms of subjectivity in the selection process and over-emphasis of the competitive, compared to the cooperative, aspects of science. In addition, the small number of fields in which the Nobel Prize is given obviously limits both the scope of scientific fields covered and the actual number of prize-winners. However, the degree of public and scholarly attention afforded the Nobel Prizes and their recipients in itself justifies treatment of the subject. Science is an accumulative endeavor, so that past excellence is supportive of future efforts. The prestige and international recognition associated with the Nobel Prize often enhances the reputation of research in the laureate's field and country. This in turn tends to attract bright and capable students and stimulate further innovative activity in nation's research effort.

The foundation of the Nobel Prizes can be attributed to the generosity of Alfred Bernhard Nobel.[30] The prize for economics is the only one not directly established by Nobel. Since 1969, when the Nobel Prize in this field was first awarded, U.S. economists have received six, while prizes have also been presented to an economist from each of the following countries: the United Kingdom, Austria, Norway, Sweden, the Netherlands, and the Soviet Union.

The number of Nobel Prize laureates in the sciences are presented in Figure 1-12 by field and date of award for those countries holding a majority of the prizes. Although the prizes are presented to individuals, information as to the location in which the outstanding work was performed provides some evidence as to the relative quality of scientific research being performed in those countries. Thus the prizes are assigned here to the laureate's country of work rather than country of birth. The prizes are categorized in terms of the year of award, but as the average time lag between the actual research and the bestowal of the Nobel Prize varies between 12 and 14 years,[31] a very general idea as to the relative health of research in a particular country at a point in time can be had by sliding back one period in the graphs.

Care must be taken in country comparisons because each laureate was counted as though a single prize had been awarded; thus, contributions may be slightly inflated when the award is shared by scientists working in the same country. This mode of tabulating Nobel Prizes was judged preferable, however, to that of counting fractions of awards for a number of reasons, among which is the fact that assigning fractional awards discriminates against the often occurring multiple awards shared between people who did essentially different work.[32] Even when the prize is shared for essentially the same work, the research is often conducted independently as in the case of the 1976 physics laureates Samuel C.C. Ting and Burton Richter, who won the prize for their simultaneous but separate discoveries of a new particle in 1974.

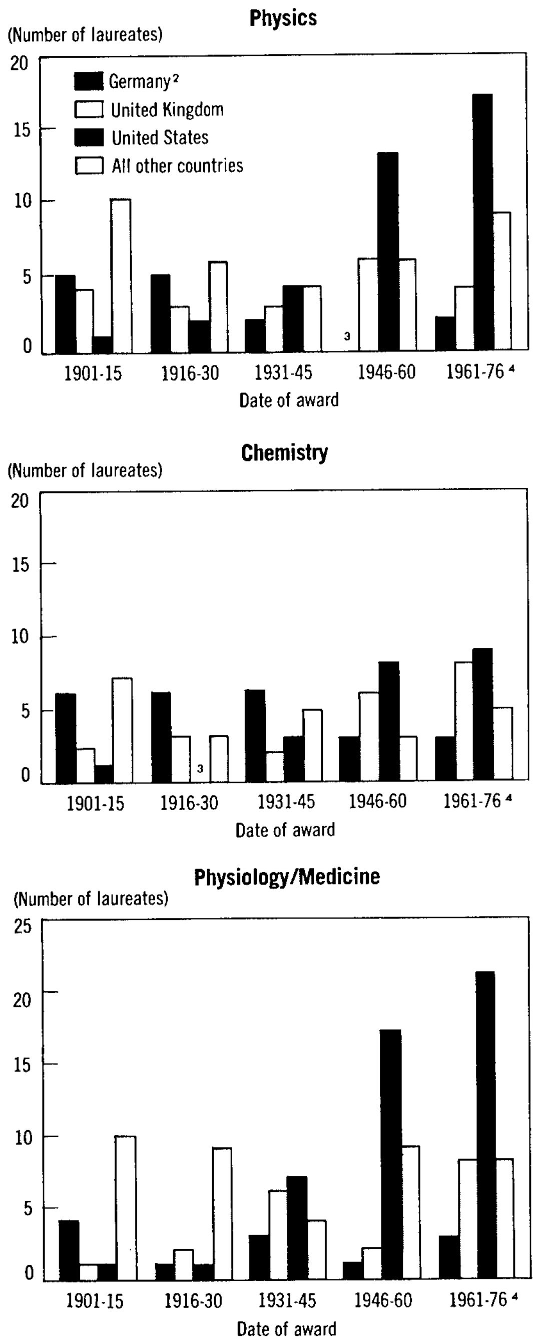
[30] A detailed account of the life of Nobel, the establishment of the various prizes and their administration can be found in *Nobel, the Man and His Prizes* (Stockholm: Nobel Foundation, 1972).

[31] However, substantial variation in the lag time exists. See the following footnote for an example.

[32] For instance, the 1973 Nobel Prize for Physiology/Medicine was shared between Karl Ritter von Frisch (West Germany) for his work with bees in the 1920's, Konrad Lorenz (West Germany) for his behaviorist psychiatric studies in the 1930's, and Nikolass Tinbergen (United Kingdom) for his 1942 work with baby gulls. Although the three men were cited for "their discoveries concerning the organization and elicitation of individual and social behavior patterns," their research was not in any way physically or temporally connected.

1-12

Number of Nobel Prize laureates by field for selected countries, 1901-76 [1]



[1] Presented by location of award-winning research.
[2] Includes East Germany before 1946.
[3] West Germany received no prizes for physics in 1946-60; the United States none for chemistry in 1916-30.
[4] This period consists of 16 years rather than 15.
REFERENCE: Appendix Table 1-12.

Figure 1-12 indicates that although it ranked very low in the number of physics laureates during 1901-30, the United States improved in the number of prizes assigned to its scientists during 1931-45, and came to dominate the field from 1946 to the present. The United Kingdom is second both in total prizes given to physicists and in physics prizes awarded its scientists during the most recent period, 1961-76. Germany ranks third in total prizes awarded to its scientists in the field of physics. All other countries accounted for 33 percent of all Nobel Prizes in the field of physics, with France and the Soviet Union together responsible for 40 percent of these "other country" prizes (see Appendix Table 1-12).

Awards in the field of chemistry were most often presented to German scientists from 1901 to 1945; however, chemists in the United States and the United Kingdom have most often been awarded the prizes since 1945. German scientists have received 27 percent of the total chemistry awards while chemists in the United States and the United Kingdom have each obtained 24 percent.

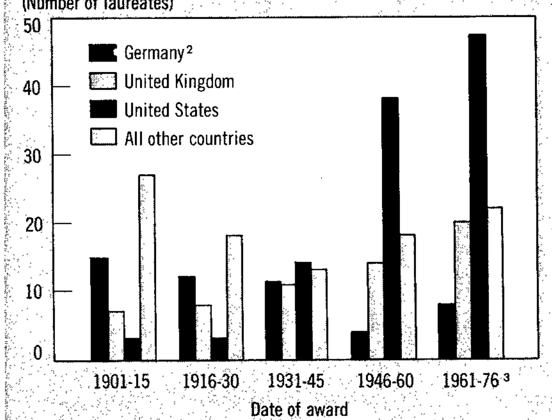
Since 1946, Nobel Prizes in the field of physiology/medicine have most often been awarded to U.S. researchers and medical scientists. However, in the most recent period (1961-76), there was a substantial increase in the number of Nobel Prizes presented to U.K. scientists in this field. Nobel Prizes in physiology/medicine are less concentrated in terms of nationalities of laureates than any other field.

Examination of Figure 1-13 shows that since the initiation of the Nobel Prize in 1901, scientists in the United States have received the greatest number of awards in all fields combined, surpassing all other countries since the 1931-45 period. Even though U.S. scientists received all the Nobel Prizes awarded in 1976, the U.S. share of total prizes has remained at a fairly constant level of about 50 percent over the period since 1946. During the period 1961-76, scientists in the United States were awarded a smaller percentage of prizes in chemistry and physiology/medicine than in the previous fifteen years, with only a slight increase showing for physics. U.S. scientists received 53 percent of the prizes for physics, 36 percent for chemistry, and 53 percent for physiology/medicine in 1961-76.

Additionally, in proportion to each nation's population, U.S. scientists have received a

1-13

Total Nobel Prize laureates in chemistry, physics, and physiology/medicine for selected countries, 1901-76 [1]



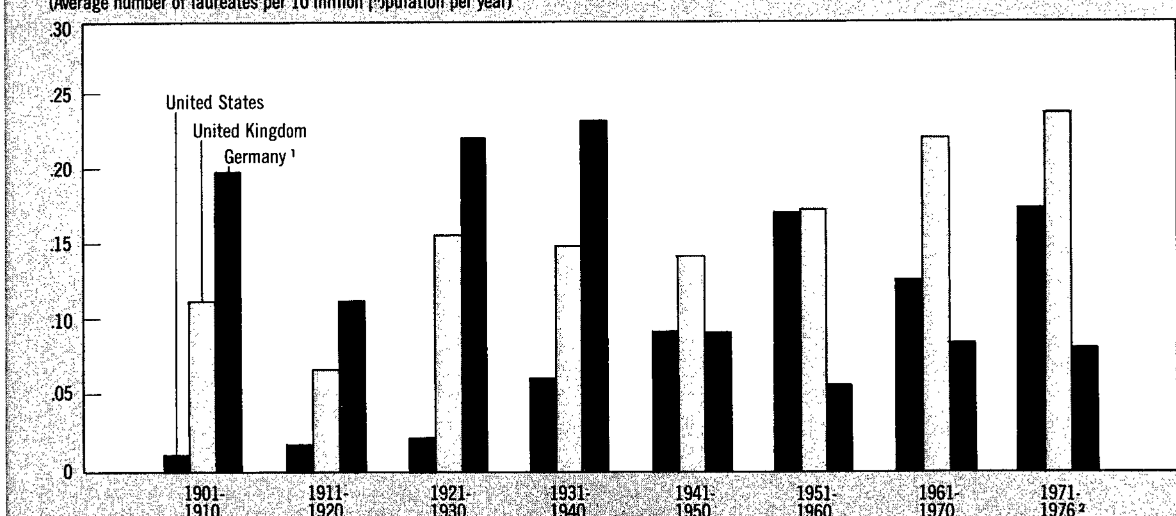
[1] Presented by location of award-winning research.
[2] Includes East Germany before 1946.
[3] This period consists of 16 years rather than 15.
REFERENCE: Appendix Table 1-13.

smaller proportion of prizes than the United Kingdom in each decade since 1901 (Figure 1-14). In fact, using this indicator, such countries as the Netherlands and Switzerland have received a relatively greater number of prizes in some years than either the United States or the United Kingdom (see Appendix Table 1-14).

Although the Nobel Prize is considered by far the most prestigious scientific award, there are similar distinctions for those areas of science not covered by the Nobel Prize. The Fields Medal for Mathematics is one example. Established in 1936, the medal is awarded at each International Congress of Mathematicians on a quadrennial basis. So far the United States has received the largest percentage of medals (35 percent), followed by France (20 percent) and the United Kingdom (15 percent). Single medals have been presented to mathematicians from the Soviet Union, Italy, Sweden, Finland, Norway, and Japan.

1-14

Nobel Prize laureates in science per 10 million population for selected countries, 1901-1976



[1] Includes East Germany before 1946.
[2] This period consists of only 6 years rather than 10.
REFERENCE: Appendix Table 1-14.

TECHNOLOGICAL INVENTION AND INNOVATION

International patterns in technological invention and innovation are presented in this section along with data on the role of the United States in disseminating technical know-how. The term "invention" is differentiated from "innovation" in that "invention" is a stage in the innovation process and consists in the demonstration of a new technical idea by the building and testing of a workable example of a new process, device, or usable material. "Technological innovation" is here defined as the introduction of new or improved products, processes or services into general use. Examination is made of patents granted in the United States and abroad, including the identification of industrial areas in which foreign expertise and involvement in U.S. patenting activity seem to be high. Various government policies aimed at fostering innovation are discussed as well as the degree to which countries rely on their own inventions when introducing innovations. Indicators of the extent of U.S. transactions in the purchase and sale of intangible property such as patents, licenses, and manufacturing rights serve here as an indicator of U.S. involvement in international technology transfer.

The patent balance

Patents, which represent actual or potential advances in technology, can serve as an indicator of the inventive output of different countries. Inventions of new products and processes must be of sufficient originality to be patented, but their technical and economic significance can vary substantially.[33] Patents, furthermore, are granted in various countries on the basis of differing criteria. The rigor of tests for originality vary, as does the extent and effectiveness of protection afforded by the patent.

For these reasons, the absolute number of patents granted by individual countries is not an adequate indicator for the purposes of international comparisons. It is more meaningful to compare the number of patents granted to nationals with those granted to foreigners in each country. Since it is generally more costly to obtain a patent in a foreign country, an index[34] has been developed which reflects the relative success of countries producing inventions of sufficient potential significance to warrant international patent protection.

Figure 1-15 presents the total number of patents granted to U.S. nationals by ten countries (Canada, West Germany, Japan, U.S.S.R., the United Kingdom, and the following five European Economic Community countries as a group: Belgium, Denmark, Ireland, Luxembourg, and the Netherlands), the number granted to nationals of these countries by the United States, and the resulting U.S. balance.[35] These countries are major trading partners with the United States, and were responsible for 72 percent of all foreign patenting in this country during 1975.[36]

The patent balance of the United States fell about 47 percent between 1966 and 1975, as shown in Figure 1-15. The decline was due both to an increasing number of U.S. patents of foreign origin and a leveling off and eventual decline in 1973-75 in the number of foreign patents awarded to U.S. citizens. Foreign patenting increased overall in the United States during the period by 91 percent. In fact, the share of U.S. patents granted to foreign residents has more than doubled in the last 15 years, reaching a level of 35 percent in 1975.[37] Japan has played a major role in the increase of foreign patenting in the United States. The number of patents granted to Japanese inventors by the United States in 1975 was more than five times that of 1966.

Although there seems to be a general increase of interest in all countries in foreign patenting due to the expansion of markets, in general, the rate of growth of patentable ideas of international merit seems to be expanding at a greater rate in other countries than in the United States. The erosion of the U.S. patent balance with

[33] There is reason to believe that many potentially valuable inventions are not patented but rather are classified as trade secrets by corporations.

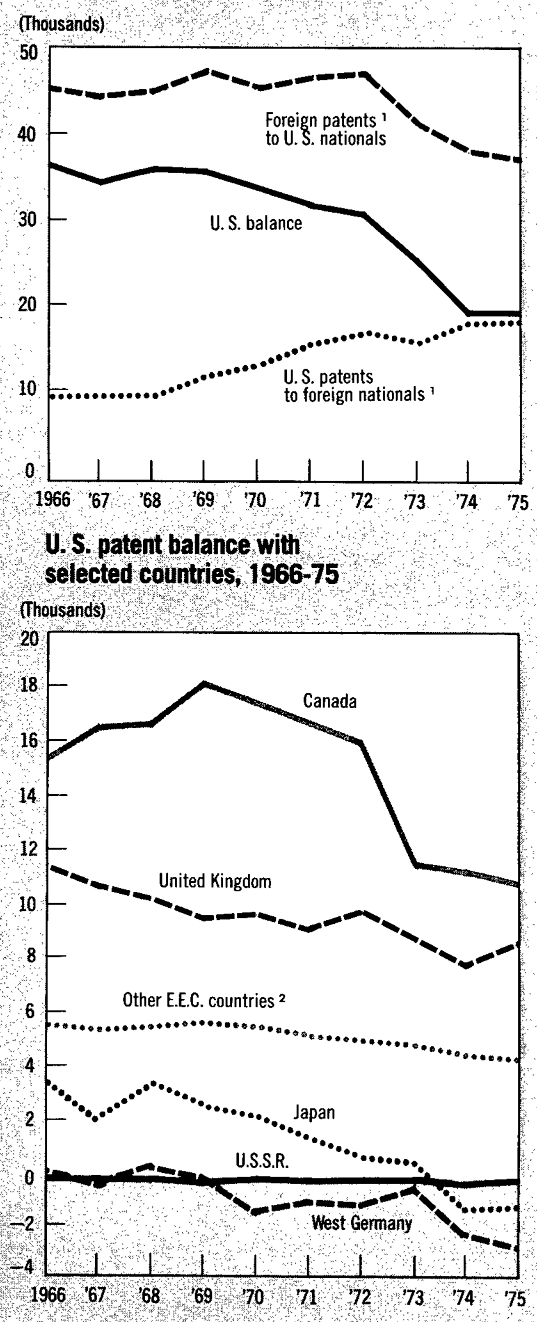
[34] The number of patents granted to U.S. nationals by foreign countries minus the number of patents granted to foreign nationals by the United States.

[35] Throughout this chapter, patent activity is discussed in terms of date of patent grant rather than date of patent application, thus reflecting earlier inventive activity, the current average pendancy period is 20 months.

[36] France and Italy were not included in the index due to the lack of comparable data.

[37] *Indicators of the Patent Output of U.S. Industry, II*, Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, July 1976 (A study commissioned specifically for this report).

1-15
Patents granted to U. S. nationals by selected foreign countries and to foreign nationals by the United States, 1966-75



¹ Including only Canada, West Germany, Japan, the United Kingdom, U.S.S.R., Belgium, Denmark, Ireland, Luxembourg, and the Netherlands. Data for France and Italy are not reliable for use in this indicator.

² Other European Economic Community (E.E.C.) countries include Belgium, Denmark, Ireland, Luxembourg, and the Netherlands.

REFERENCE: Appendix Table 1-15.

selected countries can be seen in Figure 1-15. The United States has a favorable but declining balance with Canada, the United Kingdom and the group of five specified European Economic Community countries and a negative balance with West Germany, and Japan. The U.S. balance with West Germany has been negative since 1969, but was positive (albeit declining since 1968) with Japan through 1973. A negative balance with Japan was registered in 1974, due equally to the increase of patents filed in the United States by Japanese inventors and to the decrease of patents granted to U.S. citizens by Japan. In 1975 the negative balance with Japan improved slightly due to the 11 percent increase in Japanese patents granted to U.S. inventors.The U.S. balance with Canada dropped sharply after 1972 as a result of a 29 percent reduction in the number of patents granted by Canada to U.S. inventors between 1972 and 1975.[38]

Foreign origin patents by product field

The growth of foreign patenting in the United States occurs across a wide spectrum of fields rather than being only focused in specific technologies. Examination of foreign participation in 1973-75 patent activity demonstrates this distribution. Table 1-16 ranks the product fields by percentage of foreign involvement. It is interesting to note that for five categories considered the most R&D-intensive in the United States,[39] the average of the percent of foreign participation in U.S. patent activity was 37 percent during the period 1973-75.

Foreign origin patenting in R&D-intensive product fields

This section further analyzes patenting in R&D-intensive product fields by examining those invention areas (defined in terms of classes

[38] This reduction may have been caused indirectly by new controls placed on foreign companies by Canada. The high degree of U.S. patent activity in Canada has been influenced by the amount of U.S. direct investment and the relative ease of obtaining a patent in Canada.

[39] These categories are nonelectrical machinery, aircraft and parts, chemicals, electrical machinery, and professional and scientific instruments. For a discussion of R&D-intensiveness, see the "Productivity and Balance of Trade" section of this chapter, and the "Outputs from Industrial R&D" section of the "Industrial R&D and Innovation" chapter.

1-16. Percent of total U.S. patents[1] granted to foreign inventors by product field, 1973-75

Product field	Percent
Drugs and Medicines	46
Aircraft and parts	43
Primary metals	40
Chemicals, except drugs	40
Textile mill products	39
Food and kindred products	35
Nonelectrical machinery	34
Motor vehicles and other transportation equipment, except aircraft	34
Electrical equipment, except communications	33
Professional and scientific instruments	33
Communication equipment and electronic components	32
Stone, clay, glass, and concrete products	31
Rubber and miscellaneous plastics products	31
Fabricated metal products	28
Petroleum and natural gas extraction and petroleum refining	16

[1] Calculated on the basis of original references rather than cross references in the patent file and by date of grant.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *U.S. Patent Activity in Fifty-Two Standard Industrial Classification Categories, 1963-75*, July 1976 (A study commissioned specifically for this report).

and subclasses in the U.S. Patent and Trademark Office classification scheme) which are determined to be among the most active in terms of patents granted.[40] For each R&D-intensive produce field, Table 1-17 lists six U.S. patent categories which were among those experiencing the highest growth rates from 1973 to 1975. The patent areas are then ranked by the average percent of patents in each that were issued to residents of foreign countries. The foreign country which has filed the largest number of patents for the period 1973 to 1975 is also listed by product field. The country which maintained the leadership in total patents over the extended period 1963-75 is included in parentheses if it differs from the current leader. It is not surprising to find that both Japan and West Germany hold the leadership among foreign nations in most of the patent product fields. It is interesting to note that in the last several years Japan has moved ahead of West Germany in several cases.

U.S. patent activity of selected countries

Since the overall foreign participation in U.S. patent activity is growing rapidly, it is interesting to examine individual country performances for separate product fields. The following section is an attempt to highlight the U.S. patenting characteristics of those countries which have been most successful in seeking U.S. patents from 1963 to 1975. Figure 1-18 shows the number of U.S. patents obtained for the six most active countries, while Appendix Table 1-16 includes information on the number of U.S. patents by product field for ten additional active countries.[41]

[40] It should be noted that this material is based on both original patent references and cross-references in the patent files, whereas the other information on patents in this chapter is based on original references alone. Because the study was conducted from the viewpoint of U.S. patents in active product fields, it does not necessarily represent the invention areas which are experiencing the greatest absolute foreign growth.

[41] The information in the following section is based on *U.S. Patent Activity in Fifty-Two Standard Industrial Classification Categories 1963-1975*, Office of Technology Assessment and Forecast, U.S. Patent Office, 1976 (A study commissioned specifically for this report).

1-17. Foreign participation in active patent categories by R&D-intensive product fields, 1973-75

Patent area[1]	Percent of U.S. patents to foreign inventors	Foreign leader(s)
Chemicals and allied products		
Six-membered heterocyclic ring compounds	55	Germany[2]
Five-membered heterocyclic ring compounds	47	Germany
Heterocyclic plant growth regulators	37	Germany
Preparation of synthetic resins	33	Japan
Removal of sulfur from vapors	32	Japan (Germany)
Prostaglandins	31	Sweden
Nonelectrical machinery		
Sterling engines	69	Sweden (Netherlands)
Internal vaporizing oil engines	69	Japan (Germany)
Transport systems for recorders	46	Japan
Internal combustion engines equipped with emission control devices	45	Japan
Vehicle controlling or indicating devices	34	Japan
Machine readable encoded records	26	Japan (Germany)
Electrical equipment and communications		
Pulse modulated communication systems	46	Japan
Preparation of semiconductors	38	Japan (Germany/Japan)
Display control systems	35	Japan
Insulated gate semiconductors	29	Japan
Switchboard substations	21	Japan
Wellbore signalling devices	5	Sweden/France/Germany
Aircraft and missiles		
Computerized braking systems	55	Germany
Gas turbines having diverse air paths	26	United Kingdom
Operation of turbine-type power plants	25	Germany/France (Germany)
Gas turbines with expansible joints	23	United Kingdom
Automatic missile guidance systems	13	France
Methods of operating solid propellant reaction motors	6	Germany
Professional and scientific instruments		
Single lens reflex cameras	60	Japan
Illuminated timepieces	47	Japan
Holography	45	Japan
Bone surgery	44	United Kingdom
Optical measuring and testing by light reflection	34	United Kingdom (Germany)
Optical measuring and testing by light transmission or absorption	31	Japan (Germany)

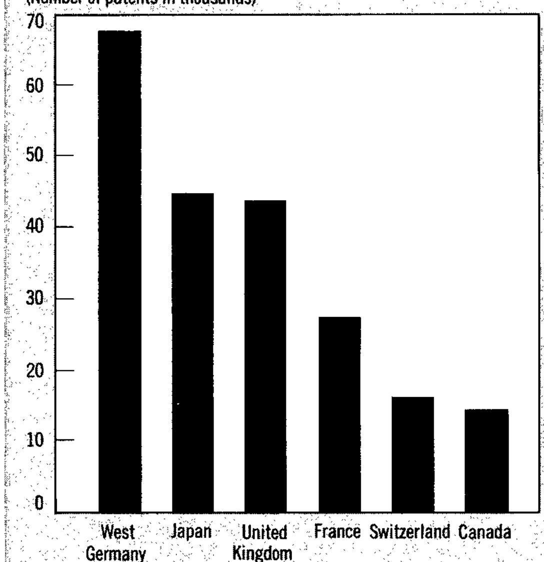
[1] The patent areas shown are the six most active areas within each product field.
[2] "Germany" refers to West Germany.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *Active Patent Classification in R&D-Intensive Industries and Fifty-Two Standard Industrial Classification Categories, 1963-75,* July 1976 (A study commissioned specifically for this report).

1-18

Number of U. S. patents granted to selected countries, 1963-75

(Number of patents in thousands)



REFERENCE: Appendix Table 1-16.

West Germany. Since 1963, West German inventors have obtained the largest number of foreign-origin U.S. patents (67,122), placing first in ten of the fifteen major product fields examined. The greatest German patenting activity in the U.S. has historically taken place in the areas of nonelectrical machinery, particularly engines and turbines, and in chemicals, especially basic industrial inorganic and organic chemicals. In 1975, however, Germany was first among foreign nations in only six of the major product fields, but second in the remaining nine. Germany was surpassed by Japan in 1975 in three categories: rubber and miscellaneous plastics; electrical equipment except communication equipment; and stone, clay, glass and concrete products. Likewise, Japan took the leadership in the field of professional and scientific instruments in 1972.[42] However, Germany still maintained first place in these fields for total patents from 1963-75.

Japan. Second in the total number of U.S. patents granted to foreign inventors during the period (44,761), Japan has received the greatest number of its patents in the categories of chemicals (particularly agricultural chemicals), nonelectrical machinery, and communication equipment and electronic components. Since 1970, however, Japan has dramatically increased its patent activity by over 100 percent in every major category except two—textile mill products (64 percent) and electrical equipment (88 percent). In two categories—aircraft and parts, and motor vehicles and other transportation equipment—increases of 567 percent and 461 percent respectively were registered. Even those categories in which Japan was already strong have experienced large increases since 1970. Thus, chemicals increased 127 percent; nonelectrical machinery, 154 percent; and food and kindred products, 293 percent. In 1975, Japan ranked first among the foreign countries in U.S. patenting in eight of the major SIC categories and second in all the rest.[43] These findings are significant in that they seem to give evidence contrary to the widespread beliefs that: (1) Japanese R&D efforts are narrowly focused on specific technologies, and (2) that the Japanese technological development strategy, which has concentrated on adapting other nations' technologies, would come to a standstill when confronted with the need to rely on its own abilities to innovate and invent. In addition, the great diversity and rapid increase of Japanese-origin U.S. patents gives further evidence of Japan's interest in U.S. market penetration in nearly all industries.

United Kingdom. The United Kingdom ranked third among foreign countries in the number of U.S. patents (43,710) awarded to its residents for 1963-75. During this period, it was particularly active in obtaining patents in the categories of nonelectrical machinery (especially engines and turbines), chemicals, motor vehicles and other transportation (particularly motorcycles and guided missiles and space vehicles),

[42] In most cases this was a result of Japan increasing its percentage of patents rather than any decrease on the part of Germany. However, in the case of electrical equipment, the number of patents attributed to Japan increased by 8 percent while those granted to German residents decreased by 10 percent.

[43] It may be of interest to note that the United States likewise plays an important role in foreign patenting in Japan. In 1975 the inventors from the United States were granted 51 percent of all foreign-origin and 11 percent of the total number of patents filed in Japan; see *Industrial Property*, World Intellectual Property Organization, December 1976.

and aircraft and parts. The United Kingdom was first in the number of foreign-origin U.S. patents in only one category—petroleum and natural gas extraction and petroleum refining,[44] but held the second or third place in all the remaining categories except drugs.

France, Switzerland, and Canada were the next most active countries in terms of total patents issued by the United States during 1963-75 (27,389, 16,156 and 14,652 respectively). France was strong in the categories of motor vehicles and other transportation equipment, especially motorcycles; guided missiles and other space vehicles, and aircraft and parts. French inventors were also active in obtaining patents in the categories of nonelectrical machinery and chemicals. Switzerland ranked third in the category of total foreign drug patents, although the United Kingdom surpassed them during 1975. Chemicals, especially industrial inorganic and organic chemicals, was another active U.S. patent area for Switzerland over the entire period. Canada had the third highest number of U.S. patents granted to foreign nations in the petroleum and natural gas extraction and petroleum refining category during 1963-75. Almost 43 percent of the Canadian patents filed in the United States during the period were in chemicals or nonelectrical machinery.

Foreign participation in U.S. patenting activity seems to be highly concentrated within each of the industrial areas. Table 1-19 shows that for each product field over 50 percent of the foreign activity from 1963 to 1975 can be attributed to only three countries. In fact, for ten of the fifteen product fields, three countries account for at least 60 percent of the U.S. patents of foreign origin.

International trends in technological innovation

The process leading to innovation is a complicated and to date little understood one. Previously considered a two-step process (from invention to innovation), it actually involves a wide variety of activities often including basic research, the establishment of technical feasibility or the first conception of the future innovation, applied research, establishment of performance criteria or product specifications, preliminary engineering, prototype or pilot plant construction, tooling and construction of manufacturing facilities, and manufacturing and marketing start-up. Various studies have been conducted on the relative importance to the innovation process of such factors as research and development,[45] user needs and involvement,[46] market demands,[47] communication patterns,[48] characteristics of the innovating firm,[49] and so forth. One thing does seem clear: technological innovation is an important factor in determining the productivity, economic growth and international position of developed nations.[50]

The point has often been made that the United States would do well to examine and learn from other countries' experiences in fostering innovation. A recent NSF-sponsored study of five countries (France, West Germany, the Netherlands, the United Kingdom, and Japan)[51] attempted to examine the effectiveness of government mechanisms for influencing technological change. Analysis was made of twelve mechanisms which governments use to affect the innovation process itself, to increase

[44] It should be noted, however, that this category of U.S. patents had the lowest foreign share of all categories considered.

[45] S. Myers and D. Marquis, *Successful Industrial Innovations*, National Science Foundation (NSF 69-17).

[46] *Success and Failure in Industrial Innovation: Report on Project SAPPHO*, Science Policy Research Unit (London: University of Sussex, Center for Industrial Innovation, 1973) and Eric von Hippel, "The Dominant Role of Users in the Scientific Instrument Innovation Process," MIT Sloan School of Management, Working Paper 75-764, January 1975.

[47] James M. Utterback, "Innovation in Industry and the Diffusion of Technology," *Science*, Vol. 183 (February 15, 1974), pp. 620-626.

[48] Thomas J. Allen, "Communication Networks in R&D Laboratories," *R&D Management*, Vol. 1, (January, 1970), pp. 14-21.

[49] William J. Abernathy and James M. Utterback, "Innovation and the Evolving Structure of the Firm," Harvard University Graduate School of Business, Working Paper HBS 75-18, June 1975.

[50] For further discussion of this topic refer to: Robert Gilpin, *Technology, Economic Growth, and International Competitiveness*, U.S. Congress, Joint Economic Committee, 94th Congress, 2d Session, 1975; *The Conditions for Success in Technological Innovation*, Organisation for Economic Co-operation and Development, 1971; Raymond Vernon, "International Investment and International Trade in the Product Life Cycle," *Quarterly Journal of Economics*, Vol. 80, (May 1966); and E.F. Denison, *Why Growth Rates Differ: Postwar Experience in Nine Western Countries* (Washington, D.C.: The Brookings Institution, 1967).

[51] *National Support for Science and Technology: An Examination of Foreign Experience*," (Cambridge, Mass.: Center for Policy Alternatives, Massachusetts Institute of Technology, 1976).

1-19. Concentration of foreign patenting in the United States for the three most active countries, by product field, 1963-75

Product field[1]	Three most active countries	Percent of all foreign origin patents registered in category
Chemicals, except drugs	West Germany	29
	Japan	18
	United Kingdom	13
	Total	60
Nonelectrical machinery	West Germany	27
	United Kingdom	17
	Japan	13
	Total	57
Communication equipment and electronic components	Japan	26
	West Germany	20
	United Kingdom	17
	Total	63
Fabricated metals	West Germany	24
	United Kingdom	19
	Japan	13
	Total	56
Professional and scientific instruments	West Germany	26
	Japan	23
	United Kingdom	14
	Total	63
Electrical equipment except communication equipment	West Germany	24
	Japan	18
	United Kingdom	17
	Total	69
Motor vehicles and other transportation equipment except aircraft	West Germany	29
	United Kingdom	20
	France	14
	Total	63
Rubber and miscellaneous plastics	West Germany	23
	United Kingdom	18
	Japan	17
	Total	68
Drugs and medicines	Japan	21
	West Germany	18
	Switzerland	12
	Total	51
Aircraft and parts	West Germany	29
	United Kingdom	25
	France	15
	Total	69
Stone, clay, glass, and concrete products	West Germany	20
	United Kingdom	20
	Japan	17
	Total	57

1-19 (Continued)

Product field[1]	Three most active countries	Percent of all foreign origin patents registered in category
Primary metals	Japan	21
	West Germany	20
	United Kingdom	16
	Total	57
Textile mill products	West Germany	28
	United Kingdom	20
	Japan	17
	Total	65
Food and kindred products	Japan	36
	West Germany	14
	United Kingdom	11
	Total	61
Petroleum and gas extraction and petroleum refining	United Kingdom	26
	West Germany	19
	Canada	12
	Total	67

[1] Listed in order of volume of foreign patents registered.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *U.S. Patent Activity in Fifty-Two Standard Industrial Classification Categories, 1963-75*, July 1976 (A study commissioned specifically for this report).

the quantity and quality of the intellectual resource base, and to ameliorate the adverse effects of technological change on the environment and society.

The study indicates that while all of the countries have some type of effort under each mechanism, certain policies and programs enjoy more emphasis or success than others depending on national goals and characteristics. For instance, France has made extensive efforts in the creation of markets through procurement programs and trade accords. Both the French and the West Germans have devoted large sums of money to risk-sharing programs, with funding in Germany being targeted toward key technologies. Japan, the United Kingdom, France, and West Germany all have supported the creation of specialized institutions responsible for the financial support of individual inventors and small firms involved in patenting new products or creating new enterprises. Of the five countries, the United Kingdom has the healthiest venture capital market, and Japan is the only one which has been able to reduce competitive risk in the implementaton of new technologies through import restrictions and foreign license and patent controls.

Another cross-country study conducted at the University of Sussex reviewed recent empirical research on technological innovation and compared the characteristics of government policies towards industrial innovation in France, West Germany, the Netherlands, and the United Kingdom.[52] One of the findings showed that although there were major differences in the organizational arrangements for financing civilian R&D, there were some similarities. For instance, all four countries maintain government-sponsored technological institutes and laboratories specifically related to nuclear, space, aircraft and advanced electronics technologies. In fact, government-funded

[52] K. Pavitt and W. Walker, "Government Policies Towards Industrial Innovation: A Review," *Research Policy*, Vol. 5 (May 1976), pp. 11-97.

civilian R&D activities were found to be heavily concentrated in these areas. Each country also provided general and technical services to industry and supported programs for financing R&D in industrial firms outside the above technology areas.

The following section provides indicators of international trends in technological innovation based on a study of 500 technological innovations introduced into the marketplace between 1953 and 1973 in six countries.[53] The selection of the 500 innovations was done by an international panel from an initial list of 1,160 innovations identified by a literature survey. An additional 150 innovations suggested by the panelists brought the universe size to 1,310. The 500 innovations were selected from these 1,310 on the basis of ranking of innovations by the panel in terms of their adjudged technological, economic or social importance.

The innovations included in the study are representative of a wide range of product areas and industrial sectors. Some examples of the innovations considered are listed below:

Nuclear reactors	Oil skimming system to treat oil spills
Oral contraceptives	Ultrasonic plastic bonding
Urethane foams	Synthesis of cortisone
Electron beam welding	Double knit fabrics
High voltage electronic cables	Weather satellites
EMI brain scanner	Cryo-surgery

Certain caveats should be kept in mind as these data are discussed. The actual number of innovations studied is relatively small because only the most important innovations were considered rather than the less significant but more numerous innovations which may effect a greater overall impact in the long run. The relatively small data base, particularly for countries other than the United States, is an important limitation on interpreting national trends.

Distribution of major innovations by selected countries

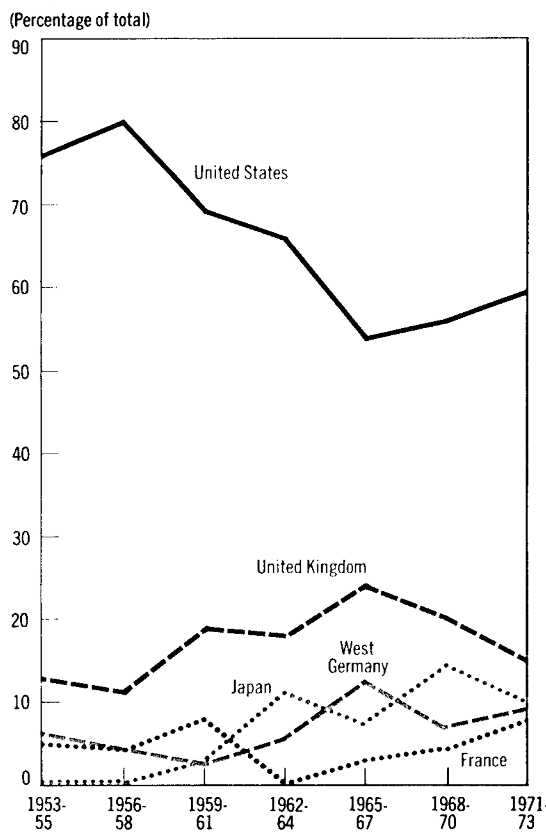
The distribution of the major innovations studied is presented by year and country of market introduction in Figure 1-20.[54] The United States is shown to be responsible for initiating the largest percentage of innovations determined to be major. However, from the mid-1950's to the mid-1960's, the U.S. share fell from 80 to 54 percent of the innovations. This corresponded to an overall increase in the next-ranked U.K. innovations from 11 to 24 percent, and increases of the West German and Japanese shares of innovations of 8 and 7 percent, respectively. The 5 percent difference in the U.S. share of innovations from 1965-67 to 1971-73 was paralleled by a corresponding 9 percent decrease in the share of innovations accounted

[53] *Indicators of International Trends in Technological Innovation*, Gellman Research Associates, Inc., 1976.

[54] The Canadian innovations were omitted from this report because they were few in number, making any detailed analysis inconclusive. Hence, the data base covers 492 rather than 500 innovations.

1-20

Major technological innovations by selected countries, 1953-73[1]



[1] By year of market introduction

REFERENCE: Appendix Table 1-17.

for by the United Kingdom. Japan experienced the largest absolute gain over the entire 21-year period although its share of total innovations considered was only 10 percent by the early 1970's.

Table 1-21 presents the distribution of innovations among the four market types for each of the five countries.[55] Half of the innovations were directed towards the producer goods market, while 19 percent were aimed at government markets and 16 percent were consumer product-oriented. An additional 15 percent were for internal use, for example to improve or modify a production process of the innovating organization itself. Of those innovations studied, 28 percent of those from the United States were aimed at more than one market, while 26 percent of the West German innovations were multiple market-oriented. Only 16 percent of the Japanese, and 2 percent of the U.K. innovations were directed toward multiple markets. Almost half of the U.S. innovations (47 percent) were producer-goods oriented. The United Kingdom had the highest concentration of innovations aimed at producer goods (72 percent), while French firms seemed to produce innovations directed more toward the government (45 percent) than toward other markets.

[55] An innovation initially targeted for one market may have subsequently been introduced in another, e.g., an innovation directed to government consumption may later be adopted in industry. It has been assumed that those innovations which are directed at more than one market are ultimately more useful to a nation's economy and have been so weighted in Table 1-21.

Not only were the innovations directed toward diverse markets but they were also introduced by a wide range of industries.[56] The U.S. innovations were highly concentrated in R&D-intensive industries such as scientific instruments, electrical and communications equipment, chemicals and allied products, and nonelectrical machinery. Innovations in the United Kingdom were often connected with the aircraft industry while those of Japan were principally found in the primary metals or electrical equipment and communications industrial areas. West German innovations were often associated with the machinery industry while French innovations were widely distributed among a variety of industries.

Invention/Innovation Relationships

To what extent did each of these countries rely on its own inventiveness? Although the connection between a product and its underlying invention is sometimes distant or uncertain, most of the inventions underlying the innovations studied were found to have originated in the same country.[57] The U.S. innovations were predominantly based on domestic inventions or technologies (93 percent); of the 21

[56] Each innovation was assigned to a Standard Industrial Classification (SIC) on the basis of the SIC category for the firm responsible for developing the innovation.

[57] The data in this section are based on the following innovation counts: United States, 319 innovations; United Kingdom, 85; Japan, 34; West Germany, 33; and France, 21, for a total of 492 innovations.

1-21. Percent distribution of innovations by type of market and country, 1953-73[1]

Country	Consumer goods	Producer goods	Government	Internal use	Total[2]
United States	19	47	19	15	100
United Kingdom	2	72	13	13	100
West Germany	7	55	24	14	100
Japan	16	52	6	26	100
France	10	35	45	10	100
Total for these countries	16	50	19	15	100

[1] The data base used here consists of 484 responses, some of which were multiple responses. Because some of the innovations were aimed at more than a single market group, they have been counted more than once in calculating these percent distributions.

[2] Detail may not add to totals because of rounding.

SOURCE: Gellman Resarch Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1976, Appendix D.

inventions which the United States imported from abroad, one-third were acquired from the United Kingdom. The United Kingdom, in turn, relied on domestic inventions for 88 percent of its innovations; Japan, 85 percent; and West Germany, 79 percent. France was the only country in which all of the innovations examined were based on domestic inventions.

THE U.S. ROLE IN INTERNATIONAL TECHNOLOGY TRANSFER

Technology transfer is a subject which has been given a great deal of attention recently although the concept itself is not a new one. Controversy has surfaced as to the responsibilities of developed nations to developing countries in the provision of technical know-how. This has manifested itself in the form of a proposed international Code of Conduct for Technology Transfer[58] which is still being debated. Controversy also exists within the United States itself over how much technology is desirable to transfer, what impact it is likely to have on the U.S. economic and strategic position, and what additional controls, if any, should be instituted.[59]

The diffusion of technology occurs via several modes: person-embodied, through the travel or immigration of scientists and engineers or attendance at technical conferences; embedded technology, in the form of goods or services sold domestically or exported; and foreign direct investment and licensing, which usually combines portions of both of the above two. Direct investment and licensing are the primary channels for the transfer of technology by American firms.

This section describes the extent of technology transfer occurring through the sale and purchase of technical know-how in the form of patents, licenses, manufacturing rights and similar intangible property.[60] Information on the U.S. receipts and payments of fees and royalties can act as an indicator of the amount of know-how transferred by the United States and the directions and destinations of the technology flows.

Royalties are payments for the utilization of copyrights or trademarks, while licensing fees are associated with charges for the use of a patent or industrial process. U.S. transactions in these areas have been divided into two categories, essentially those associated with U.S. direct investment (e.g., between U.S. firms and their overseas subsidiaries) and those between independent organizations, or unaffiliated transactions. Because the terms of agreement between affiliated firms can be influenced by business considerations other than the actual value of the technology concerned, unaffiliated receipts and payments are more likely to reflect the true value of the technology transferred. Nevertheless, it is essential to examine direct investment-related receipts and payments because that is where the bulk of the transactions is taking place. Additionally, it is necessary to look at both categories of transfers because the differing economic or technological development strategies of individual nations may influence the type and volume of transfer activity preferred. Thus, most Japanese business agreements occur in the unaffiliated category while those of Canada are associated largely with direct investment.

Several caveats should be mentioned here. Royalties and fees are normally paid over the term of the contract, rather than upon delivery, so that payments in any given period relate to

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[58] The United Nations Conference on Trade and Development (UNCTAD) has been working on an international agreement on terms of technology transfer with sections on general principles, national regulation, obligations of concerned parties and methods of resolving disputes. The developing countries, represented by the "Group of 77," have insisted on a strict code of conduct while the Group B (industrial) countries have favored voluntary guidelines. In May 1976, at the UNCTAD-IV Meeting, the United States joined other nations in an agreement to work for a code of conduct as long as it was completely voluntary and equally applicable to technology suppliers and recipients, regardless of their ownership or political persuasion.

[59] One proponent of strict control, particularly of vital design and knowledge, is the U.S. Department of Defense. For a detailed explanation of this position see: *U.S. Technology—DOD Perspective: A Report of the Defense Science Board Task Force on Export of U.S. Technology,* U.S. Department of Defense, Office of Defense Research and Engineering, 1976. On the other side, the Council on International Economic Policy stated in its 1976 annual report: "There is no conclusive evidence that in the overall, foreign direct investment and licensing by American firms have hurt U.S. economic welfare." *International Economic Report of the President,* Council on International Economic Policy, Executive Office of the President, 1976, p. 118. See also a study on the subject prepared for the Bureau of International Labor Affairs, U.S. Department of Labor: Jack Baranson, *International Transfers of Industrial Technology by U.S. Firms and Their Implications for the U.S. Economy,* December 1976.

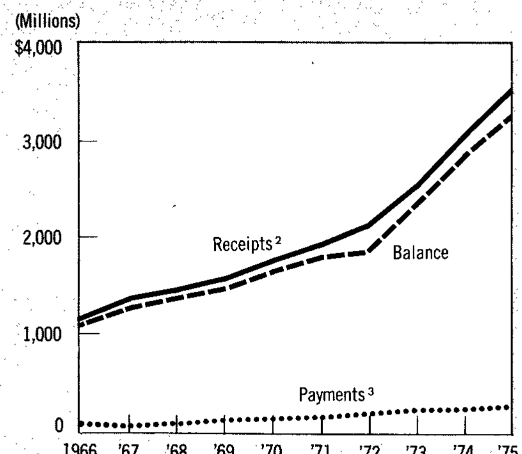
[60] Other forms of technology transfer are dealt with in separate sections of this chapter.

technology transferred in previous years as well as in the present. Annual changes in total receipts and payments of royalties and fees are influenced by the timing and duration of the payments specified in individual agreements and changes both in the value and number of technology transfer transactions.

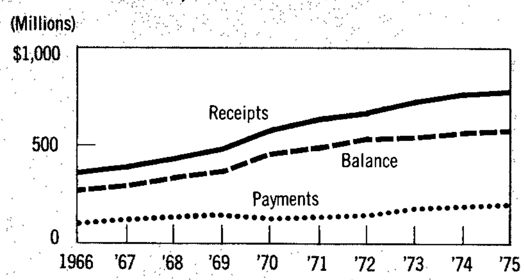
Figure 1-22 shows the dollar value of U.S. net receipts and payments and the resulting balance for both direct investment-related and unaffiliated transactions. Estimates for 1975 show net receipts associated with direct investment to be $3,526 million while unaffiliated receipts totaled only $759 million. Receipts of royalties and fees from affiliated firms have expanded more rapidly than those from unaffiliated firms over the period 1966 to 1975 (203 percent total increase, or 13 percent average annual increase, compared to 115 percent total increase or 9 percent per year for unaffiliated receipts).

1-22

U. S. direct investment balance in royalties and fees transactions,[1] 1966-75



U. S. unaffiliated balance in royalties and fees transactions,[1] 1966-75



[1] Represents total receipts and payments for the use of intangible property such as patents, licenses, management fees, etc. Excludes film rental receipts.

[2] Direct investment-related receipts measure the net transactions between U.S. firms and their foreign affiliates.

[3] Direct investment-related payments measure the net transactions between U.S.-based foreign affiliates and their foreign parents.

NOTE: Data for 1975 are preliminary.
REFERENCE: Appendix Table 1-18.

The direct investment-related royalties and fees balance for the United States (net receipts minus net payments) experienced an almost 200 percent increase over the period 1966 to 1975. Rapid growth has occurred particularly since 1972, with the affiliated technology transfer balance increasing at an average annual rate of almost 19 percent, while the unaffiliated balance concurrently grew at an average annual rate of only 5 percent. This suggests that the United States has increased its role in the transfer of technology and that U.S. firms prefer to retain an equity interest in the use of their tangible property.

The destinations of the flows of U.S. know-how are presented in Figures 1-23 and 1-24. U.S. technology has been highly sought by and transferred to industrialized countries, particularly Western Europe, with 78 percent of affiliated and 85 percent of unaffiliated purchases being made by developed countries in 1975. Almost 49 percent of direct investment-related royalties and fees and 45 percent of unaffiliated receipts came from Western Europe in 1975.

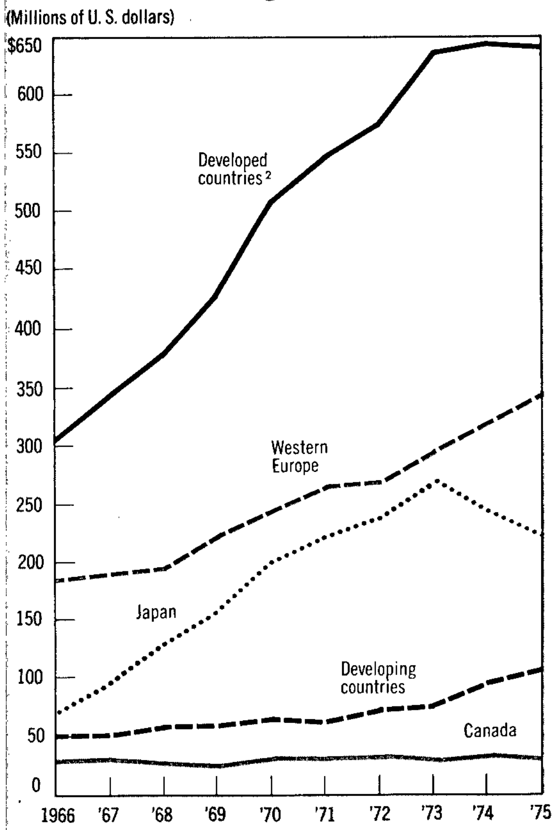
Japan has traditionally purchased U.S. know-how via unaffiliated sources, since direct investment has been highly discouraged. In 1972, Japan was responsible for 37 percent of all unaffiliated receipts for royalties and fees as compared to only 5 percent of direct investment-related transactions. Since 1972, however, there has been a decrease in the Japanese share of unaffiliated purchases of U.S. know-how (from 37 percent to 30 percent in 1975) with a corresponding but small increase in affiliated technology transfers (up to 7 percent in 1975 from 5 percent in 1972). This may reflect the liberalization of Japanese policy towards foreign capital inflow which occurred between 1971 and 1974.[61]

Most of the U.S. receipts of royalties and fees from Canada are direct investment-related. Of

[61] Consultations with Dr. Terutomo Ozawa, International Economics Professor, Colorado State University, and the Japanese Embassy, Washington, D.C.

1-23

U. S. receipts of royalties and fees for unaffiliated[1] foreign residents, 1966-75



[1] Represents receipts and payments between U.S. residents with residents or governments of foreign countries for the use of intangible property such as patents, copyrights, or manufacturing rights. Excludes fees and royalties related to U.S. foreign direct investments. Excludes film rentals.

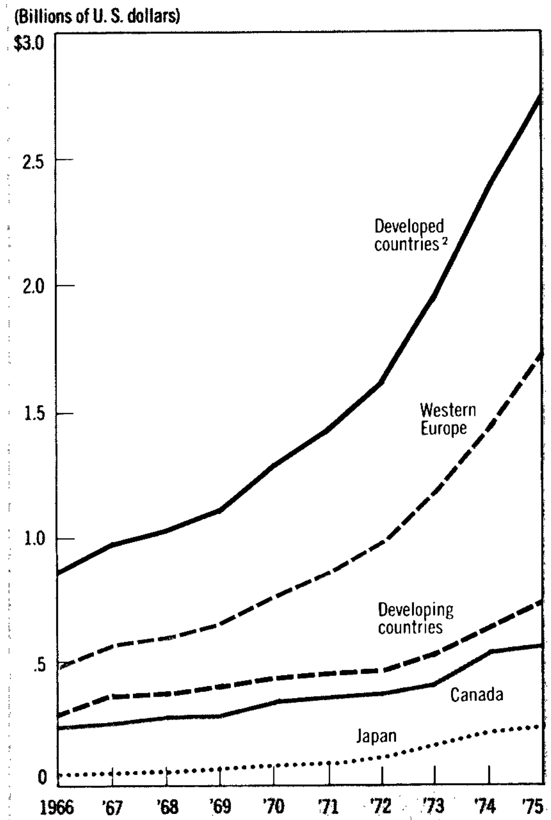
[2] Developed countries included here are Western Europe, Japan, Canada, Australia, New Zealand, and the Republic of South Africa.

NOTE: Data for 1975 are preliminary.

REFERENCE: Appendix Table 1-19.

1-24

U. S. receipts of royalties and fees from direct investment abroad, 1966-75[1]



[1] Represents net receipts of payments by U.S. firms from their foreign affiliates for the use of rights or intangible property such as patents, techniques, processes, formulas, designs, trademarks, copyrights, franchising, manufacturing rights, management fees, etc.

[2] Developed countries included here are Western Europe, Canada, Japan, Australia, New Zealand, and the Republic of South Africa.

NOTE: Data for 1975 are preliminary.

REFERENCE: Appendix Table 1-20.

total receipts from Canada in 1975 ($603 million), 94 percent were direct investment-related compared to 6 percent unaffiliated transactions. U.S. know-how is most often transferred to developing countries between U.S. firms and their subsidiaries rather than between independent organizations. Direct investment-related receipts accounted for 87 percent of all receipts from developing countries in 1975.

Since 1971, developing countries have increased their purchases of U.S. know-how; receipts for royalties and fees from developing countries increased 69 percent between unaffiliated organizations and 62 percent between affiliated firms during the period 1971-1975. However, during this same period, the share of transfers accounted for by developing countries decreased slightly for direct investment-related transactions (from 23 to 21 percent), and increased only slightly (from 10 percent to 14 percent) for unaffiliated transactions.

Although the United States is a net transferor of know-how, the U.S. purchase of foreign technology as expressed in payments for royalties and fees has grown since 1966 at an

average annual rate of almost 16 percent for affiliated and 10 percent for unaffiliated payments. Most of the foreign know-how purchased by the United States in 1975 came from Western Europe (73 percent), while Canada accounted for an additional 22 percent.

Much of the recent growth in U.S. payments for foreign technology can be attributed to the increase in direct foreign investment in the United States.[62] Thus, direct investment-related payments[63] to Western Europe increased more than unaffiliated payments from 1972 to 1975 (61 percent and 39 percent respectively). If the recent trend towards increased foreign direct investment in the United States continues and if Western Europe and Japan maintain advanced levels of sophisticated technology, U.S. payments for foreign know-how will correspondingly continue to grow. This may not be altogether a negative factor, however. A recent study of several technology-intensive industries[64] indicates that foreign companies are investing in the United States more to take advantage of the large, politically-unified and stable market than to have access to U.S. technology. It also suggests that the United States probably receives a net technological benefit from this phenomenon due to the necessity that foreign companies introduce their most sophisticated technologies in order to compete effectively in the U.S. market.

PRODUCTIVITY AND BALANCE OF TRADE

National and international trends of productivity are presented in this section, as well as measures of the role of R&D in the U.S. balance of trade. Comparative figures are shown for several major developed countries in terms of real Gross Domestic Product per employed civilian and output per man-hour in the manufacturing sector. An analysis of U.S. exports and imports of manufactured products relative to their R&D intensiveness is an attempt to identify the importance of R&D to the U.S. balance of trade. This indicator is also used to determine the balance of trade in R&D-intensive products between the United States and various other nations.

Technological change and productivity

Productivity can be defined as the amount of output derived from productive activity divided by the amount of inputs used in production, or in other words, output per unit input. Inputs include labor, raw materials, capital (largely plant and equipment), and common resources (e.g., air and water). Growth in productivity reflects increased efficiency in the conversion of resources into useful goods and services by a firm, industry, or a country.

Many factors affect productivity growth: technological change, improved labor skills and education, increases in capital intensity, improved organization of production, imported technology, or changes in the social barriers to economic efficiency. The relative influence of these factors on productivity is not known with accuracy, but, it is generally agreed that technological change is an important factor in productivity growth. An improvement in technology usually increases productivity by increasing the amount of output per unit input.[65]

R&D is today one of the major sources of technological change, although such change can result from other sources such as independent inventions, or on-the-line improvements in production techniques. Despite the fact that many conceptual and measurement problems have not been completely resolved, empirical studies do provide reasonable persuasive evidence that R&D has had a significant positive effect on the rate of productivity increase in the

[62] The foreign direct investment position showed record 23 percent increases both in 1973 and 1974, followed by a substantial increase of 19 percent in 1975 to $26.7 billion. In the previous decade, foreign direct investments grew less than 7 percent per year. See Leonard A. Lupo and Gregory G. Fouch, "Foreign Direct Investment in the United States in 1975," *Survey of Current Business* (August 1976), p. 34. For a detailed study of foreign investment in the United States, see "Benchmark Survey of Foreign Direct Investment in the United States, 1974," *Survey of Current Business*, (May 1976), pp. 35-51.

[63] Payments by U.S. subsidiaries to their parent companies overseas for the right to use intangible property.

[64] Assembly of Engineering, in cooperation with the Office of the Foreign Secretary, National Academy of Engineering, *Technology Transfer from Foreign Direct Investment in the United States*, National Research Council, 1976.

[65] See *Technological Innovation and Federal Government Policy: Research and Analysis of the Office of National R&D Assessment*, National Science Foundation (NSF 76-9) for a summary of recent research examining the relationship between R&D, technological change, and productivity.

industries and time periods that have been studied.[66]

The importance of productivity lies in its contribution to national goals—higher living standards, better health care, a cleaner environment, improved public services, national security, and the like. These goals can be more easily obtained if more productive use is made of available resources. Alternatively, productivity gains may require some trade-offs with other national objectives if they result in the increased use of available resources.

Interest in productivity growth and technological change has been heightened by the current debate about the lag in U.S. productivity growth relative to other industrial nations.[67] To compare U.S. productivity to other countries, several measures can be used such as real Gross Domestic Product per employed civilian, and output per man-hour. The former is a general approximate measure and the latter is more sector-specific, restricted here to manufacturing. Output per unit of labor is used to measure productivity because estimates of output per unit of labor plus capital are not available, and past studies indicate that changes in output per unit of labor parallel changes in output per unit labor plus capital.[68] International comparisons of productivity are difficult because of differences in sources and methodology and limitations on the availability of data. Therefore, small differences in productivity between nations and particularly over short periods may not be significant. Emphasis should be placed on general trends in any interpretation of the indicators.

[66] Charles T. Stewart, Jr., "A Summary of the State-of-the-Art on the Relationship between R&D and Economic Growth/Productivity," *Research and Development and Economic Growth/Productivity*, Papers and Proceedings of a Colloquium, National Science Foundation (NSF 72-303), pp. 11-13.

[67] See *Productivity: An International Perspective*, U.S. Department of Labor, Bureau of Labor Statistics, 1974; and testimony presented in *Federal Research and Development Expenditures and the National Economy*, Hearings before the Subcommittee on Domestic and International Scientific Planning and Analysis, House Committee on Science and Technology, April 25-May 5, 1976.

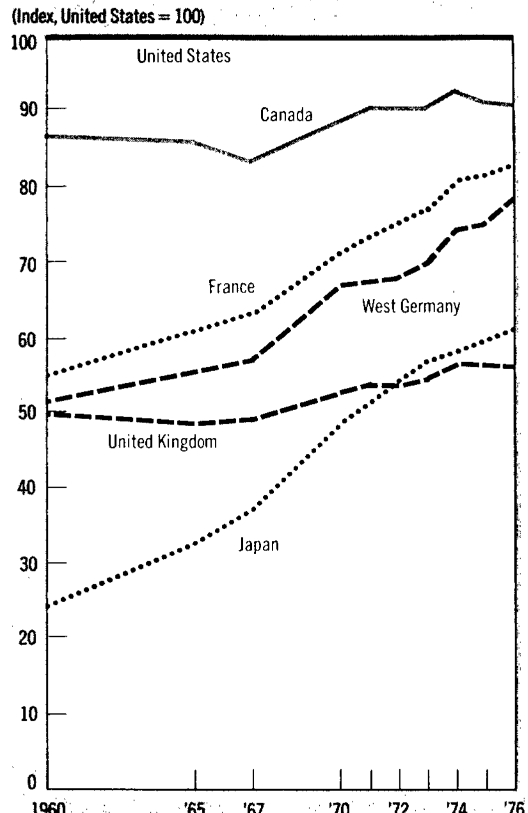
[68] See Rolf Piekarz and Eleanor Thomas, "U.S. Productivity Growth: An Assessment of Perceptions and Prescriptions," Office of Policy Research and Analysis, National Science Foundation, in *Hearings before the Special Subcommittee on the National Science Foundation of the Committee on Labor and Public Welfare*, U.S. Senate, 94th Congress, 1st Session, on S. 1539 and S. 1478 to authorize appropriations for activities of the National Science Foundation and other purposes, March 14 and April 21, 1975, pp. 139-177.

In terms of real Gross Domestic Product per employed civilian, the level of U.S. productivity exceeded that of France, Japan, West Germany, Canada, and the United Kingdom during the 1960-1976 period (Figure 1-25). Productivity growth relative to U.S. levels was generally higher in Japan, France, and West Germany than in Canada or the United Kingdom throughout the period; however, Canadian productivity levels were only about 9 to 13 percent lower than those of the United States. Productivity relative to U.S. levels grew at an average annual rate of 2.6 percent in France and West Germany from 1960 to 1976, when their productivity levels respectively were about 17 and 23 percent below

1-25

Real Gross Domestic Product per employed civilian, for selected countries compared with the United States, 1960-76[1]

(Index, United States = 100)



[1] Output based on international price weights to enable comparable cross-country comparisons.

NOTE: Estimates are shown for 1976.

REFERENCE: Appendix Table 1-21.

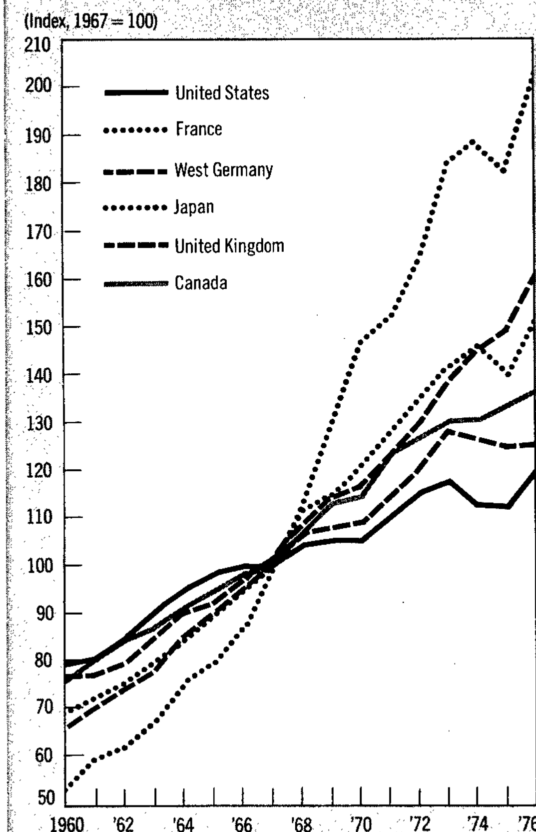
that of the United States. Productivity growth in Japan was the highest of all five countries over the period (5.8 percent annual rate), although the level was almost 40 percent below that of the United States in 1976. This measure of productivity suggests that France, West Germany, and particularly Canada are approaching the U.S. productivity levels.

Trends in productivity are more commonly measured in terms of output per man-hour. Output per man-hour may be influenced not only by labor, but also by such factors as technological innovation, scale of production and improved management techniques. This index is developed separately for each country and is used to measure the change in productivity over time in that country; it does not, however, permit cross-country comparisons of actual productivity levels.

Relative productivity in terms of output per man-hour in manufacturing is presented for five countries in Figure 1-26. The U.S. productivity gain between 1960-76 was the smallest of these five countries (55 percent) and more than five times less than increases in Japan (289 percent), which had the largest gains. The U.S. productivity rate dropped almost 4 percent from 1973 to 1975. However, preliminary estimates for 1976 show that the U.S. productivity rate rose almost 7 percent from the 1975 level. Japan, France and West Germany experienced even greater productivity gains—13 percent, 10 percent, and 8 percent respectively. Since the United States started from a relatively high level of productivity in 1960, it is to be expected that those countries starting from a much lower productivity base would enjoy greater growth rates. However, it is also undeniable that a continued slowdown in U.S. productivity growth rates coupled with accelerated growth abroad may have serious long-term implications for the nation's economic position in the world.

1-26

Relative productivity[1] in manufacturing industries by selected countries, 1960-76



[1] Output per man-hour.
NOTE: Estimates are shown for 1976.
REFERENCE: Appendix Table 1-22.

Balance of trade in R&D-intensive manufactured products

The U.S. international trade position depends upon a number of factors, including the prices of its products, the effectiveness of its international marketing, trading arrangements with other countries, and its performance in technological innovation. The relationship between R&D, technological innovation, and a nation's trade has not yet been precisely determined. However, studies suggest that the role of technology in U.S. trade is quite important.[69] The following examination of foreign trade is restricted to those aspects which provide relatively direct indices of the position and performance of U.S. technology. As a result, such topics as foreign direct investment, sales of U.S. subsidiaries abroad, and the impact of multinational corporations are not discussed.

An indicator of the effectiveness of a nation's productivity level and one of the many factors which determine the international balance of trade is the "unit labor cost"—the ratio between

[69] Raymond Vernon (ed.), *The Technology Factor in International Trade*, (New York: Columbia University Press, 1970).

hourly labor costs and output per man-hour. Lower unit labor costs tend to give a nation a competitive edge in the international market because as unit labor costs decrease (productivity rates increase faster than labor costs), products can be produced at less cost, and thus sold at lower prices.[70] Even if a country enjoys a technological lead over its competitors this lead can quickly disappear given the rapid rate of knowledge transfer which exists today. If increases in a nation's unit labor costs are greater than those of other countries, a competitive advantage based on technological strength or otherwise, may be in danger of elimination. Thus unit labor costs are important to consider in an analysis of a nation's competitiveness in manufacturing.

Trends in unit labor costs in manufacturing industries for several countries can be seen in Table 1-27. U.S. unit labor costs rose moderately from 1967 to 1973. In 1974, unit labor costs rose more rapidly in the United States than in any other period since World War II. This was due to insignificant productivity rises and large gains in labor costs. However, 1976 estimates show only a slight increase in U.S. unit labor costs over the 1975 figure. From 1967 to 1975, unit labor costs moderately increased in the United States (56 percent) and Canada (51 percent) as compared to the United Kingdom (147 percent) and Japan (123 percent). By 1975, unit labor costs had increased 95 percent in France and 65 percent in West Germany from their 1967 levels. Canadian unit labor costs rose 9 percent from 1975 to 1976, to a level 65 percent above the 1967 level.

The relationship between R&D, technology and U.S. trade can be in part analyzed by the examination of the U.S. trade balance in product categories, when products are classified in terms of the relative levels of R&D investment of the industries that are the main producers of those products.[71] For this purpose those product fields corresponding to industries with (a) 25 or more scientists and engineers engaged in R&D per 1,000 employees, (b) company-funded R&D amounting to at least 3 percent of net sales, and (c) total R&D funding amounting to at least 3.5

[70] For a discussion of recent trends in unit labor costs, see Patricia Capdevielle and Arthur Neef, "Productivity and Unit Labor Costs in the United States and Abroad", *Monthly Labor Review*, Vol. 98 (July 1975); for an analysis of the roles of these trends in international trade, see *Competitiveness of U.S. Industries*, United States Tariff Commission, (T.C. Pub. 473) 1972, pp. 15-26.

[71] Only manufacturing industries (which account for nearly all industrial expenditures for R&D) are included in the analysis.

1-27. Unit labor cost[1] in manufacturing industries for selected countries, 1967-76

(Index, 1967 = 100)

Year	United States	Japan	France	West Germany	United Kingdom	Canada
1967	100.0	100.0	100.0	100.0	100.0	100.0
1968	103.3	103.4	101.7	98.5	100.1	99.9
1969	108.7	106.1	104.0	101.4	106.8	101.7
1970	116.5	112.1	111.1	114.0	121.7	107.9
1971	117.6	125.4	118.2	123.7	132.6	108.3
1972	118.1	134.0	123.9	130.0	138.7	111.9
1973	123.2	145.4	133.6	138.4	150.6	117.4
1974	140.9	187.8	158.3	152.4	184.8	131.8
1975	156.4	222.8	195.0	164.7	247.1	151.1
1976 (est.)	157.9	NA	NA	NA	NA	164.7

[1] On a national currency basis.

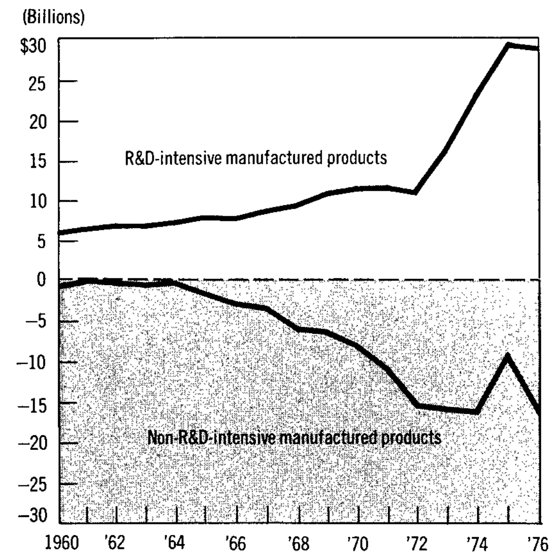
SOURCE: Department of Labor, Bureau of Labor Statistics, Office of Productivity and Technology, "Output per Hour, Hourly Compensation and Unit Labor Costs in Manufacturing Twelve Countries, 1950-1975", 1977, and other unpublished data.

percent of net sales are considered here to be R&D-intensive.[72] The product groups designated as R&D-intensive are (1) chemicals, (2) electrical machinery, (3) nonelectrical machinery, (4) aircraft and parts,[73] and (5) professional and scientific instruments. All other manufactured products are considered non-R&D-intensive.

The U.S. trade balance (exports minus imports) for these two groups of products is illustrated in Figure 1-28.[74] The trade balance for R&D-intensive manufactured products has been positive and generally rising throughout the period.[75] The most dramatic increase (166 percent) was between 1972 and 1975, with a leveling off occurring in 1976. The 1976 balance

1-28

U. S. trade balance[1] in R&D-intensive and non-R&D-intensive manufactured product groups, 1960-76



[1] Exports less imports.
REFERENCE: Appendix Table 1-23.

was almost five times greater than that of 1960 and more than 2½ times the 1972 level. In contrast, the trade balance for non-R&D-intensive manufactured goods was near zero in the early 1960's but steadily declined from 1964 to 1974. In 1975 this balance temporarily rose due to a reduction of the importation of non-R&D-intensive manufactured products caused by the general effects of the worldwide recession, a slowdown in consumer spending, a sharp decline in industrial output, and inventory liquidations. Some of the 1975 drop in imports can be traced to reductions in the quantity and/or value of product groups such as transport equipment, and metal products. However, in 1976 the non-R&D-intensive balance dropped 74 percent to -$16.5 billion, representing a return to the long term trend of an ever increasing deficit.[76] Clearly the technology-

[72] This grouping, which corresponds to R&D-intensity Group I of the "Industrial R&D and Innovation" chapter, is, of course, an approximate one. Products and industries, although fairly correlated at the gross level, do not perfectly coincide, with the result that not all products manufactured by a high R&D-performing industry can be considered R&D-intensive products. Examination of data on applied R&D by product field in manufacturing, however, shows that these fields are among the top recipients of applied R&D expenditures. See *R&D in Industry, 1974*, National Science Foundation (NSF 76-322), pp. 68-71. The United States Commerce Department has developed two other classifications of R&D-intensive categories. An analysis and comparison of the three can be found in the *International Economic Report of the President*, Council on International Economic Policy, Executive Office of the President, 1977, pp. 120-124; and Regina K. Kelly, "Alternative Measurements of Technology-Intensive Trade," Staff Economic Report, Office of Economic Research, U.S. Department of Commerce, 1976.

[73] The product field "aircraft and parts" is less extensive than the industry class "aircraft and missiles;" "guided missiles and spacecraft" (SIC 1925) has been excluded from this analysis due to its limited importance to U.S. trade and the unavailability of area of destination data for this category.

[74] The export statistics presented here include all merchandise shipped from the U.S. customs area, with the exception of supplies destined for U.S. Armed Forces abroad for their own use; shipments for relief purposes or under military assistance programs are included. The import statistics cover foreign merchandise received in the U.S. customs area. The accuracy of foreign trade data may be affected by financial incentives for respondents to misstate their actual import/export figures.

[75] The trends in U.S. foreign trade presented here were influenced by recent adjustments in the international monetary systems. In December 1971, the United States reduced the par value of the dollar; in March 1974, all of the major world currencies converted to a system of floating exchange rates. The precise impact of these changes on the U.S. trade position is not known, but in general they are thought to enhance the competitiveness of U.S. exports. A detailed discussion of this topic is presented in the *Economic Report of the President*, Council of Economic Advisers, 1975, pp. 189-219.

[76] *International Report of the President*, Council on International Economic Policy, Executive Office of the President, 1976, pp. 22-27; and U.S. Department of Commerce, Domestic and International Business Administration, *Overseas Business Reports* (77-20), April 1977, pp. 12-16.

intensive product group has been responsible for yielding surpluses and largely covering deficits in trade from specific non-R&D-intensive product groups throughout the period until 1976. Its importance in maintaining an overall favorable trade balance is unquestionable.

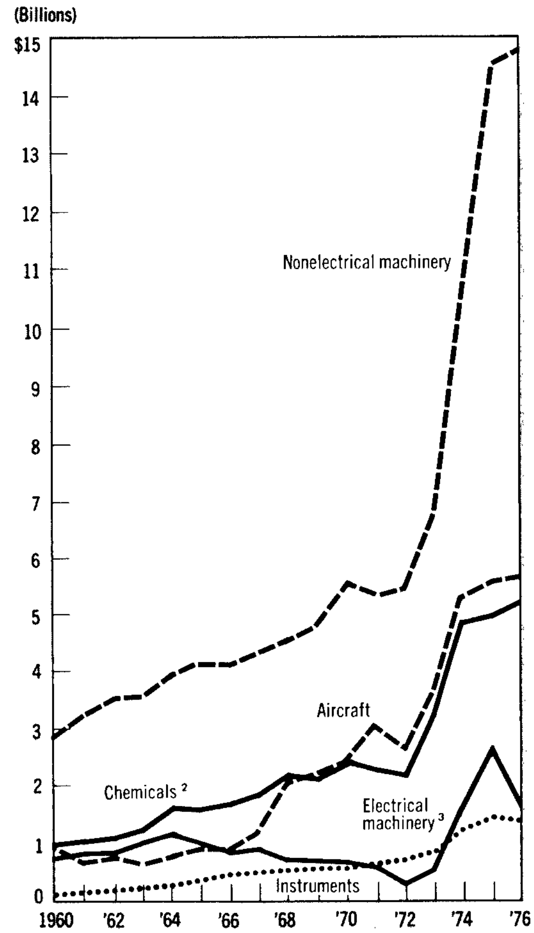
The favorable U.S. trade balance in products from specific R&D-intensive industries is shown in Figure 1-29.

> *Nonelectrical machinery* accounted for over one-half of the favorable balance in R&D-intensive products in 1976. The recent growth in the balance for this area was largely a result of increased exports of electronic computers, internal combustion engines, construction equipment, and mining and well-drilling machinery.
>
> *Aircraft and parts* contributed approximately one-fifth of the positive balance in R&D-intensive products in 1976. This group showed a decline in imports between 1973 and 1976.
>
> *Chemicals* accounted for 18 percent of the positive balance in R&D-intensive products. The recent increase in net exports of chemicals was due largely to growth in the exports of plastics, medicinal and pharmaceutical products, and manufactured fertilizers.
>
> *Electrical machinery* had a generally declining balance of exports over imports between 1965 and 1972, but showed a marked positive increase of over 700 percent between 1972-75. In 1976 the balance again decreased (31 percent) due to a surge in the importation of consumer electronics such as transceivers and TV receivers.
>
> *Professional and scientific instruments* has maintained a steady but small growth in net exports since 1960, with an upturn of 123 percent from 1972 to 1975. In 1976 this growth leveled off due to a 34 percent increase in imports.

Further insight as to the state-of-the-art in U.S. scientific and professional instruments can be obtained by examining the importation of scientific materials under the Florence Agreement.[77] This Agreement on the Importation of Educational Scientific and Cultural Materials facilitates the international flow of such materials by exempting specified categories

1-29

U. S. trade balance[1] in selected product groups, 1960-76



[1] Exports less imports.
[2] Includes drugs and other allied products.
[3] Includes communication equipment.
REFERENCE: Appendix Table 1-24.

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[77] The material in the following paragraphs was obtained from the records of the Special Import Programs Division, Domestic and International Business Administration, U.S. Department of Commerce, which is the U.S. entity responsible for determining the justification for duty-free entry based on criteria of technical need by a nonprofit organization and determination of domestic unavailability of scientifically equivalent instrumentation for the applicant's intended purposes.

from customs duties and certain other importation charges. Approval of applications from nonprofit organizations for duty-free entry of scientific instruments or apparatus is granted only after an extensive investigation process to determine that the necessary specifications of the imported foreign instrument cannot be matched by a domestically manufactured instrument or apparatus. Under this agreement, radical new technologies (such as computerized transaxial tomographers) can be imported duty free until a similar instrument, or one which can perform the same functions with equal precision, is developed in the United States.[78] Therefore, the proportion of applications approved provides additional insight on inventiveness by shedding light on where the cutting edge of scientific instrumentation manufacturing is occurring.

As of June 30, 1975, over 850 separate nonprofit institutions (including colleges and universities, hospitals, Federal and State Government agencies and public and private research organizations) have made application for duty-free entry of scientific instruments or apparatus. The largest number of applications in the United States are made for transmission electron microscopes (26 percent) and ultramicrotomes (18 percent), with scanning electron microscopes taking a low third place (5 percent).

Table 1-30 presents the percent of applications accepted for duty-free entry of scientific instruments not available in the United States. It shows that even though both the total number of applications and the percentage of those approved have declined slightly, over 90 percent of the applications decided upon were approved. This suggests that even though the U.S. trade balance in scientific and professional instruments has been positive and increasing particularly since 1972, many advanced researchers in the United States must still rely on foreign sources for the most advanced technologies (e.g., ultramicrotomes) in instrumentation. There are certain limitations which should be noted, such as the fact that only nonprofit organizations are eligible for the special importation program; only those who need or want a waiver of duty elect to become applicants; and the program applies only to instruments at the time of their shipment to the United States. In addition, applications are more likely to be made for expensive items which have high duty rates.

1-30. Percentage of applications accepted for duty-free entry of scientific instruments or apparatus without U.S. equivalents, 1967-68 through 1975-76

Fiscal year	Total applications	Total decisions[1]	Total approved	Percent of decisions approved
1967-68	844	361	351	97
1969-70	1,550	781	772	99
1971-72	1,263	822	812	99
1973-74	1,178	833	816	98
1975-76	1,059	757	704	93

[1] Consists of applications with final approvals or denials, and does not include those applications which were denied without prejudice to resubmission.

SOURCE: Special Import Programs Division, U.S. Department of Commerce, unpublished data.

There have been substantial changes over the last decade in the mix of products underlying the favorable trade balance. Several products have become increasingly important (including electronic computers, fertilizers, electronic tubes, transistors and semiconductor devices), while the contribution of other commodities (such as telecommunications apparatus) to the overall positive trade balance has declined. The mixture of growing and declining exports illustrates the complexities of the present U.S. trade position. The underlying dynamics of this position may be partially explained by the "product cycle" concept.[79] Trade in manufactured goods, according to this concept, typically follows a cycle in which the United States initially establishes a net export position with the introduction of a new product, maintains this position until the technologies and skills necessary for manufacturing the product are developed elsewhere, and

[78] Scientific instruments which are not radically new, but whose specifications cannot be matched domestically, are also eligible for duty-free entry.

[79] Raymond Vernon, "International Investment and International Trade in the Product Cycle," *Quarterly Journal of Economics*, Vol. 80 (May 1966), pp. 190-207.

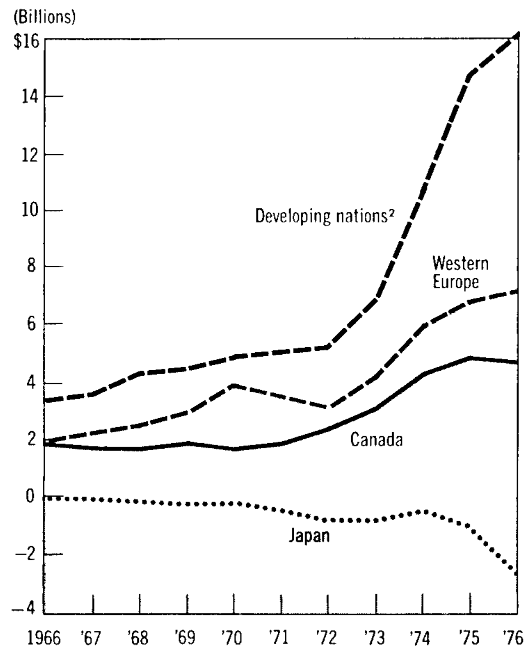
then invests abroad to minimize costs, becoming an importer as the production is standardized. This concept implies that the product structure of U.S. exports must have a continuous infusion of new products in order for the United States to maintain a favorable trade position.[80]

The favorable position of the United States in R&D-intensive manufactured products is based primarily on exports to all major U.S. markets except Japan.[81] The U.S. trade balance in these products is shown in Figure 1-31 for selected areas and countries. In 1976, the developing countries accounted for 55 percent of the positive R&D-intensive U.S. trade balance; nonelectrical machinery and chemicals were particularly large net exports for the United States in trade with these nations. In the case of trade with Western Europe (24 percent of the positive balance), the United States registered its largest net exports in the areas of aircraft and nonelectrical machinery (particularly in computers). U.S. net exports to Canada were concentrated in the areas of electrical and nonelectrical machinery.

A trade deficit in R&D-intensive manufactured products developed with Japan in the mid-1960's and persisted through 1976. From 1974 to 1976, this deficit increased 383 percent, reaching over 2.6 billion dollars, largely due to a 51 percent increase in U.S. imports from Japan. The deficit occurred primarily in electrical machinery products (particularly consumer electronics) and to a lesser degree in professional and scientific instruments and nonelectrical machinery. Only in the areas of chemicals and aircraft is the United States a significant net exporter to Japan. It might be noted also that the United States has a negative trade balance with Japan in non-R&D-intensive manufactured products.

1-31

U. S. trade balance [1] with selected nations for R&D-intensive manufactured products, 1966-76



[1] Exports less imports.
[2] Includes the Republic of South Africa in 1966 and 1967.
REFERENCE: Appendix Table 1-25.

Although not designated here as being either R&D-intensive or non-intensive, agriculture is an additional component of foreign trade which is significantly affected by the position of U.S. technology. The leading role of U.S. agriculture is due at least in part to the contributions of science and technology in such areas as the development of new hybrids; the utilization of irrigation techniques; the improvement of fertilizers, pesticides, and herbicides; and the widespread mechanization of production.[82] In 1976, the United States exported $23.3 billion of agricultural commodities (with significantly high volume in wheat, corn, and soybeans), and had a positive trade balance of $12.1 billion in agricultural commodities as a whole.[83]

[80] Although this theory has been widely accepted, a recent study by the University of Sussex of changing patterns of trade in manufactured goods within the OECD casts some doubt on the explanatory power of the product cycle theory of international trade. See W.B. Walker, "Industrial Innovation and International Trading Performance," mimeo (Brighton, England: Science Policy Research Unit, University of Sussex, in press).

[81] For a more complete discussion of these relationships see Keith Pavitt, "'International' Technology and the U.S. Economy: Is there a Problem?" in *The Effects of International Technology Transfers on U.S. Economy*, National Science Foundation, Papers and Proceedings of a Colloquium (NSF 74-21) pp. 59-77.

[82] *Agricultural Production Efficiency*, (Washington, D.C.: National Academy of Sciences, 1975).

[83] *Overseas Business Reports*, Department of Commerce, Domestic and International Business Administration, April 1977, pp. 7 and 12.

The importance of the positive trade balance in R&D-intensive manufactured products is illustrated by the fact that the net exports of such products in 1975 ($29.3 billion) were more than enough to offset the negative effects of petroleum imports ($24.8 billion) for that same year, continuing a trend of several years. In 1976, however, petroleum imports rose to $31.8 billion, surpassing the positive balance in R&D-intensive manufactured products of almost $29 billion.[84] Estimates for 1976 indicate a U.S. trade deficit of $5.87 billion (exports equaled $114.8 billion and imports were $120.7 billion).[85] Thus the positive trade balance in R&D-intensive manufactured products (almost $29 billion) was not enough to offset imports of petroleum products and consumer goods such as automobiles. This in part is a phenomenon of the rate of recovery of the U.S. economy relative to major trading partners. The 1977 *International Economic Report of the President* stated that, "despite some setbacks in 1976, present trends in technology-intensive trade appear favorable" and that "there are some grounds for optimism as technology-intensive trade balances reach two to three times their historical average."[86]

[84] *Ibid.*, pp. 7-16.

[85] *Trends in U.S. Foreign Trade for 1976*, Office of International Trade Analysis, Department of Commerce, 1977, p. 1.

[86] *International Economic Report of the President*, Council on International Economic Policy, Executive Office of the President, 1977, p. 123.

Chapter 2

Resources for Research and Development

Resources for Research and Development

INDICATOR HIGHLIGHTS

- National research and development (R&D) expenditures in the United States rose to an estimated $38.1 billion in current dollars in 1976; however, constant dollar spending of $28.5 billion was only 2.5 percent above the 1974 total.

- The estimated number of scientists and engineers (full-time-equivalent) engaged in R&D reached approximately 531,000 in 1975, slightly higher than the 1974 total but still far below the 1969 level of 558,000.

- As a fraction of the Gross National Product (GNP), national R&D spending has dropped from the high of 2.97 percent reached in 1964, falling to an estimated 2.25 percent in 1976. Estimated Federal funds for R&D in 1976 as a fraction of GNP reached 1.19 percent, while funds from all other sources remained near 1 percent.

- Measured in current dollars, estimated Federally-supported R&D expenditures climbed to a new high of $20.1 billion in 1976; however, constant dollar levels stood at $15 billion, 18 percent below the peak reached in 1967.

- The Federal Government remained the largest source of R&D funds in 1976, providing an estimated 53 percent of the total, while industry supplied 43 percent; in contrast, Federal sources provided 65 percent in 1965 to industry's 33 percent.

- R&D funds from industrial sources rose considerably in the period from 1960 to 1976, from $4.5 billion to an estimated $16.6 billion. In constant dollars, these industrial R&D expenditures reached a new high of $12.4 billion in 1976.

- In general, the Nation's R&D performers[1] increased their spending in current dollars each year since 1960; in addition, after lagging for several years, constant dollar expenditures have also begun to rise with estimated 1976 spending by most sectors showing some increase over 1974 levels.

- R&D funds for the three types of R&D activities—basic research, applied research, and development—have shown little change in proportions available to each throughout the 1970's; in 1976 basic research held nearly a 13 percent share, applied research accounted for 23 percent and development, 64 percent.

- As a fraction of the total Federal budget, R&D funds have declined substantially, falling to an estimated 6 percent in 1976 from a high of 13 percent in 1965. As a fraction of the "relatively controllable"[2] portion of the Federal budget, R&D outlays amounted to 13.5 percent in 1976—the lowest level since 1967 when they were 16.3 percent.

- National defense activities consumed the largest portion of Federal R&D funds in 1976 while civilian areas[3] and space exploration took up the remainder. National defense R&D accounted for an estimated 50 percent in 1976. Civilian areas held 37

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[1] The sectors included are industry, Federal intramural laboratories, universities and colleges with their Federally Funded Research and Development Centers, and other nonprofit institutions.

[2] That part of the Federal budget which is subject to annual appropriations, rather than determined by fixed costs and "open-ended" programs whose funds increase by law.

[3] Includes areas such as health, energy, and the environment; see Figure 2-10 for a listing of civilian R&D categories.

percent in that year, while space activities had a 13 percent share.

- Estimated current dollar funding levels for defense R&D in 1976 were 19 percent higher than those in 1974, while civilian areas advanced 35 percent during the same period (primarily due to increased funding for energy-related R&D). Support for space program R&D rose by 16 percent. In constant dollars, defense, civilian areas and space rose by 3 percent, 18 percent, and 1 percent respectively between 1974 and 1976.

- Federal obligations for the dissemination of scientific and technical information, measured in real dollars, peaked in 1968 at $435 million but fell to an estimated $321 million in 1976; the ratio of these obligations to total Federal obligations for R&D dropped below the 1970 to 1974 figure of .025-.026 to .020 in 1976.

The national research and development effort draws its support from a wide variety of public and private resources. An assessment of these resources and a review of how they may be changing over time can offer considerable insight into the status and health of U.S. science and technology.

Typically, most U.S. research and development resources go to critical areas such as national defense, health, energy, and the environment, as well as to space research, transportation and other matters of national concern. Significant resources are also used to develop new and improved industrial products and processes, and to advance the understanding of nature through programs of basic research.

All components of research and development—basic research, applied research, and development—are studied in this chapter. "Basic research" has the purpose of acquiring scientific knowledge of natural phenomena, where the *primary* aim is fuller understanding of the subject of the study, rather than specific application of the resulting knowledge. "Applied research" may have a similar purpose, but the prime aim is the potential application of the acquired knowledge. The fields encompassed in basic and applied research consist of the life sciences (including the medical sciences), physical sciences, mathematical sciences, and engineering, as well as the psychological and social sciences. "Development" consists of the use of knowledge gained from research, in conjunction with technical skills for the design and prototype construction and testing of materials, devices, processes, products, systems, and methods.

Indicators of trends and levels of activity in these scientific fields are intended to serve as a yardstick for measuring the allocation and use of financial and human resources in the Nation's R&D effort. They include several measures of the absolute and relative magnitude of these resources, as well as analyses of the sectors which supply and utilize them. Indicators of financial resources for basic research, applied research and development are also provided. Trends in Federal funds for R&D are placed in perspective with the total Federal budget, and with various broad areas of R&D activity.

Other important aspects of R&D activity include resources for research facilities, and trends in the dissemination of scientific and technical information. More detailed examination of particular areas of R&D activity and measures of output are presented in subsequent chapters.

The indicators are not presented as being comprehensive and in-depth measures of trends in the allocation and use of resources for R&D. Their shortcomings reflect both the conceptual problems in research on research and data limitations, such as the difficulty of separating R&D obligations from other programmatic obligations of Federal agencies.[4] The indicators also do not provide measures of the extent to which the resources engage the Nation's full R&D capacity. In addition, indicators have not yet been developed for gauging the general effectiveness with which the R&D resources are utilized, nor the efficiency with which these

[4] See *Federal Agencies' Contracting for Research and Development in the Private, Profitmaking Sector*, General Accounting Office (PSAD-77-66), March 24, 1977.

resources are translated into R&D activity. Another deficiency is the lack of indices of the quality of the resources directed to R&D, particularly the qualifications of the scientists and engineers involved. Data and information are also incomplete regarding the national purposes to which total R&D resources are directed; only in the case of Federal obligations can R&D resources be classified according to areas of national concern such as health, energy and national defense. In the Industry chapter of this report, some data are available regarding funds for energy, pollution abatement, defense, and space. Notwithstanding these limitations, the indicators of science and technology presented in this and other chapters represent the state of the art of U.S. science indicators.

NATIONAL RESOURCES FOR RESEARCH AND DEVELOPMENT

National commitment to the support of research and development remains strong and funding levels are at an all time high; however, actual purchasing power for R&D has been cut sharply by inflation. Total R&D expenditures for 1976 in current dollars reached an estimated $38.1 billion, 18 percent above the 1974 level of $32.3 billion and almost 3 times the 1960 figure of $13.6 billion (Figure 2-1). However, the constant dollar[5] rise to $28.5 billion in 1976 was only 2.5 percent above the 1974 total of $27.8 billion, and 5 percent below the peak figure of $29.9 billion reached in 1968.

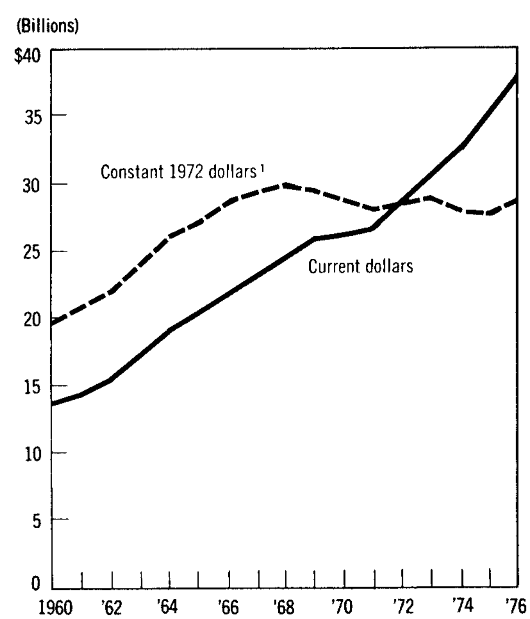
[5] Data on R&D funding are presented in both current and constant 1972 dollars in portions of this chapter and elsewhere in the report. The use of constant dollars is an attempt to reflect the reduction in the purchasing power of R&D resources which has been caused by inflation, thereby providing a more accurate indication of the real level or magnitude of R&D funding and effort. Inflation in the economy at large has reduced the purchase value of one dollar in 1972 to only 75 cents in 1976. In the absence of a price deflator specifically for R&D, the calendar year implicit price deflator for the Gross National Product (GNP) is used to convert current dollars to constant dollars; 1972 is chosen as the base or reference year in keeping with Federal statistical standards. The GNP implicit price deflator, which applies to the economy as a whole, is necessarily general in scope and is only approximately appropriate for use in connection with R&D as a whole, or with specific R&D-performing sectors, types of costs, and fields of research. However, this approximate, but uniform conversion method is preferable to various intuitive estimates of the effects of inflation on R&D.

Highly correlated with constant dollar national R&D expenditures are employment levels of scientists and engineers engaged in R&D activities (Figure 2-2).[6] On a full-time-equivalent basis, they numbered nearly 531,000 in 1975, up 1 percent from 1974, but below the high of 558,000 reached in 1969. In the period 1973-75, employment of R&D scientists and engineers increased by 9,400.

Expenditures for R&D as a percent of GNP have declined since the 1964 high of 2.97 percent (Figure 2-3). In 1974, this ratio had reached 2.29 percent, and fell to an estimated 2.25 percent in 1976. The decline which began in 1965 is due primarily to a sharp drop in R&D spending from Federal sources. The Government's R&D support fell from 1.98 percent of the GNP in 1964 to an estimated 1.19 percent in 1976. R&D expenditures from non-Federal sources stood at

[6] Scientists and engineers are defined as those performing professional scientific or engineering work in research and development, requiring a bachelor's degree or its equivalent in science or engineering. See Chapter 5 for an extensive treatment of scientists and engineers.

2-1
National R&D expenditures, 1960-76



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1975 and 1976.

REFERENCE: Appendix Table 2-1.

1.06 percent of the GNP in 1976, up from the 1964 level of .99 percent, but have remained stable at between 1.06 and 1.09 percent in the last 5 years of this period. The non-Federal share was at its highest in 1969 and 1970 (1.15 percent), peaking 5 years later than the federally supported share.

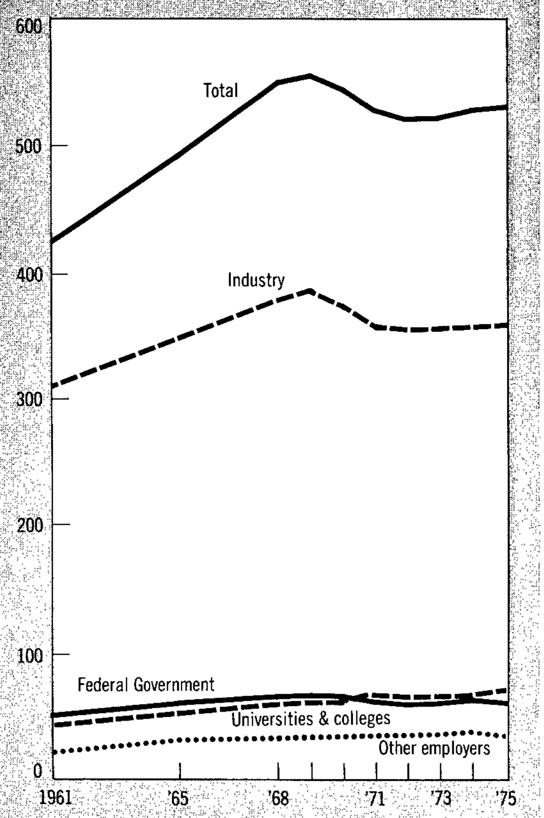
Sources of support

Since World War II, the primary source of funds for R&D has been the Federal Government, while industry provides the second largest share. Government provided an estimated 53 percent of national R&D funds in 1976 while industry accounted for 43 percent (Figure 2-4). Universities and colleges and other nonprofit institutions each held 2 percent; their shares have not varied substantially throughout the 1970's. The Government share in 1976 was down considerably from the 1960 figure of 65 percent, while the industry fraction was up from the 33 percent recorded in the same year.

In current dollars, estimated 1976 R&D expenditures from Federal sources were almost 2½ times the $8.8 billion reported in 1960. However, Federal support of R&D measured in constant dollars peaked in 1967 and declined markedly throughout the late 1960's and early 1970's. The 1976 figure stands 18 percent below the highest mark. A different profile has developed in industry-supported R&D where constant dollar amounts show a pattern of substantial growth since 1960 leading to a peak of $12.4 billion in 1976.

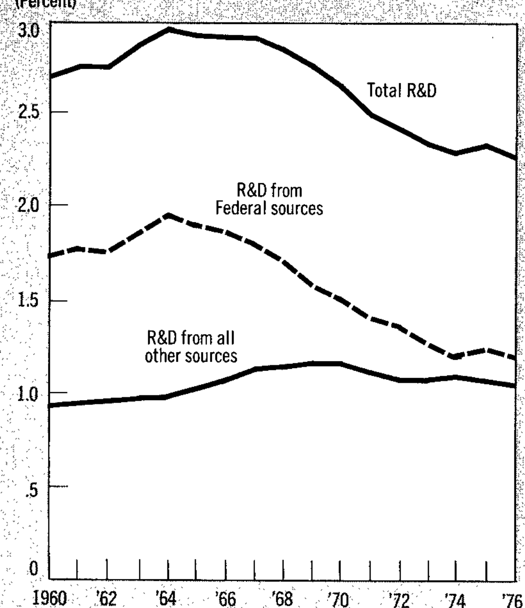
Contributions by universities and colleges have also shown sustained growth, with con-

2-2
Scientists and engineers[1] employed in R&D by sector, 1961-75



[1] Full-time-equivalent basis, excluding those employed in State and local agencies, calculated as the yearly average for the industry sector.
NOTE: Estimates are shown for 1975.
REFERENCE: Appendix Table 2-2.

2-3
National R&D expenditures as a percent of GNP by source, 1960-76



NOTE: Estimates are shown for 1975 and 1976.
REFERENCE: Appendix Table 2-3.

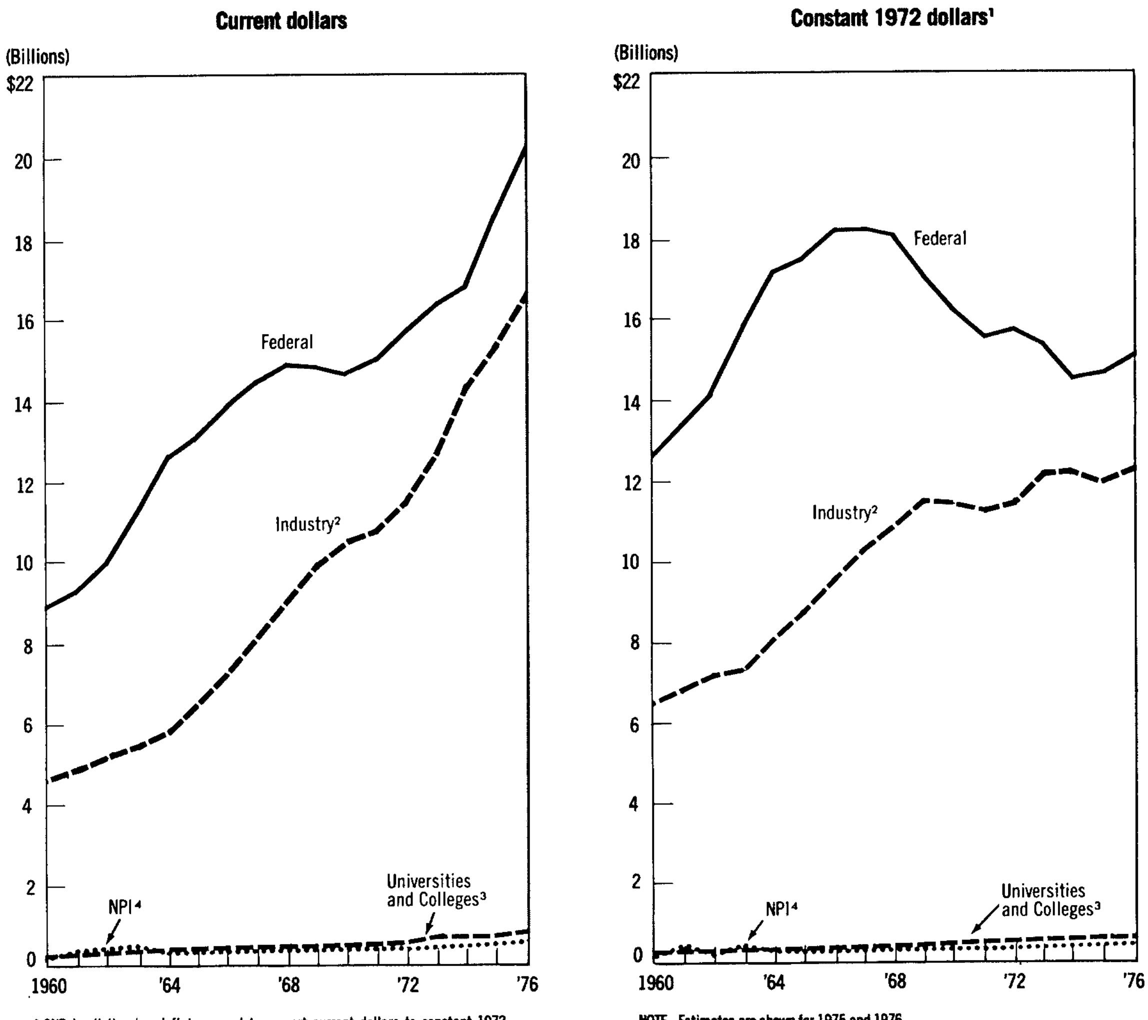
stant dollar R&D expenditures advancing 5 percent in the 1974-76 period.[7]

[7] Data in this report for universities and colleges include only separately-organized R&D; expenditures for the usual teaching/research assignments of the faculty are excluded because of the difficulties in measuring their research component.

Similar gains were made in R&D funding by other nonprofit institutions. Spending in current dollars from these sources rose to an estimated $595 million in 1976, up $96 million from the 1974 level for an increase of 19 percent. Constant dollar amounts also rose, with the 1976 level matching the peak spending seen in 1973.

2-4

National expenditures for R&D by source, 1960-76



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

[2] Data are not available on industry resources for research in the psychological and social sciences.

[3] Includes state and local sources which accounted for almost half of these expenditures since 1970.

[4] Other nonprofit institutions.

NOTE: Estimates are shown for 1975 and 1976.

REFERENCE: Appendix Table 2-4.

Expenditures by R&D-performing sectors

Increases in total national expenditures by R&D performers have been registered each year between 1960 and 1976 (Figure 2-5). However, inflationary pressures have significantly eroded these advances. For all performers, real dollar levels in 1976 remained below an earlier year of peak spending.

Total constant dollar expenditures for all sectors in 1976 remained 5 percent below the high of $29.9 billion reached in 1968, and gained only 3 percent over the 1974 level of $27.8 billion. The category "other nonprofit institutions" declined most markedly of all performers. It dropped 19 percent from its constant dollar 1970 peak of $1.2 billion to an estimated $935 million in 1976. A drop of 13 percent occurred in the 1974-76 period alone. On the other hand, universities and colleges spent 5 percent more in 1976 than in 1974, even though constant dollar expenditures remained below the 1973 peak year.[8]

Industry accounted for the largest share of national R&D expenditures, with 70 percent in 1976—down from its 78 percent share in 1960. Universities and colleges have absorbed most of the change, growing from 5 percent in 1960 to 10 percent in 1976.

Second in spending were Federal intramural laboratories with 15 percent in 1976, slightly above the 1960 level of 13 percent. Federally Funded Research and Development Centers administered by universities and other nonprofit institutions each held about 3 percent in 1976, similar to the portions held in previous years.

Scientists and engineers in R&D-performing sectors

Employment levels for R&D scientists and engineers were at their highest (558,200) in 1969 when R&D spending in constant dollars was also at its peak. They declined until 1972-73 when they leveled off above 521,000[9] then began an upswing reaching an estimated 530,500 in 1975 (Figure 2-2). Even with this increase, however, 1975 employment was 5 percent below the 1969 peak year, and only 0.6 percent above the 1974 level of 527,200. About two-thirds of all scientists and engineers employed in R&D activities have been found in the industrial sector since the late 1960's. The Federal Government and academic sectors each employ about 12-13 percent and other nonprofit institutions, about 5 percent. About 2 percent are employed in the Federally Funded Research and Development Centers administered by universities.

Basic research, applied research, and development

Development efforts absorb the largest proportion of expenditures among the three categories of R&D. They have typically accounted for about two-thirds of the total in each year since 1960 (Figure 2-6). Slightly less than one-quarter was reported as applied research, and basic research took up the remainder.

With only minor exceptions, current dollar expenditures in all three categories have advanced yearly since 1960. However, a different picture emerges when constant dollar amounts are viewed. It shows spending for development reaching a peak in 1968, then falling by 6 percent to the estimated 1976 level of $18.3 billion. A similar pattern appears in basic research with the estimated 1976 figure of $3.6 billion in constant dollars falling 11 percent below the 1968 peak. The only component which has reached a new high in real dollars is applied research, which has advanced to an estimated $6.7 billion in 1976. Between 1974 and 1976, constant dollar expenditures for basic research, applied research, and development rose by 2 percent, 3 percent, and 2 percent respectively.

Funds for each R&D component are derived largely from the Federal Government, but substantial support is received from industry, colleges and universities, and other nonprofit institutions. In basic research a shift toward increased support by the Federal and academic sectors and reduced industrial support occurred throughout the 1960's and has persisted through 1976. The Federal portion of basic research support rose to 68 percent in 1976, well above the 1960 share of 59 percent (Figure 2-7). Universities and colleges increased their share from 6 percent to 11 percent in the same period. The industry share dropped almost in half, from 28 percent in 1960 to 15 percent in 1976. Support by other nonprofit institutions has not varied dramatically over the 1960-76 period, holding at 6 percent in 1976.

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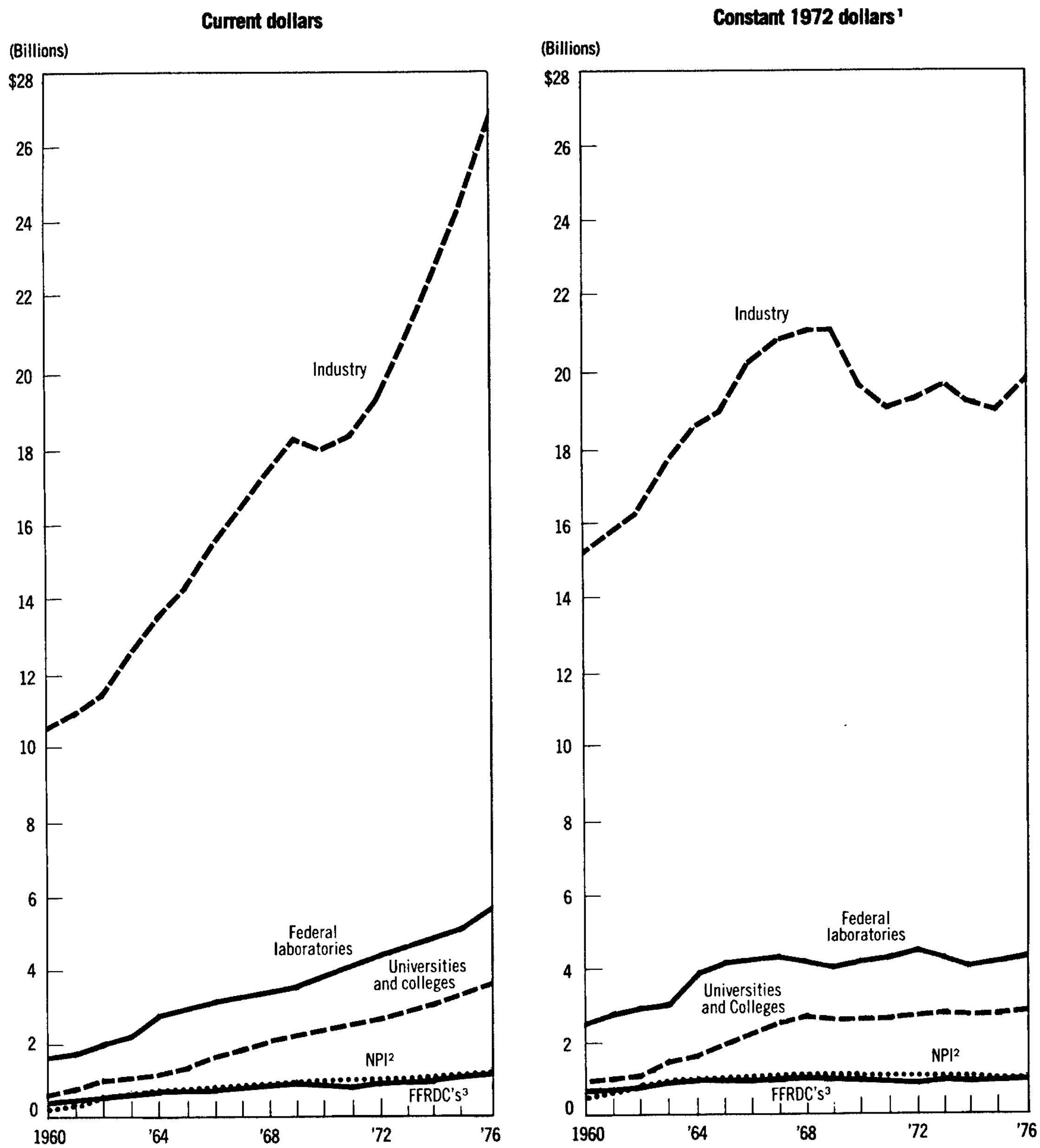
[8] Data for 1974 reflect a shift of Draper Laboratories from the university and college sector to the nonprofit sector. Total R&D spending by this laboratory was estimated at approximately $55 million in 1974.

[9] Full-time-equivalent basis.

2-5

National expenditures for R&D by performer, 1960-76



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

[2] Other nonprofit institutions.

[3] Federally Funded Research and Development Centers administered by universities.

NOTE: Estimates are shown for 1975 and 1976.

REFERENCE: Appendix Table 2-5.

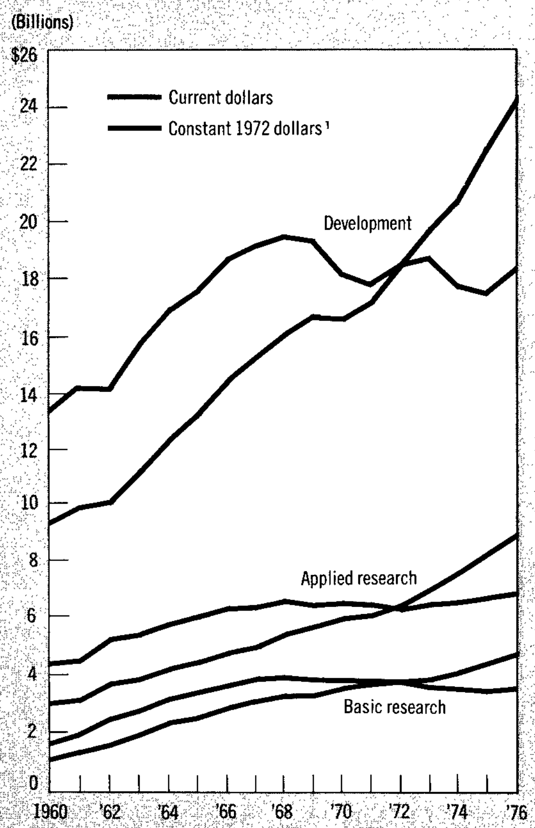
In constant dollars, 1976 expenditures for basic research from all sources except other nonprofit institutions fell below a previously attained year of peak spending, even though they rose above 1974 levels. Industrial support was 17 percent below its 1966 peak. Federal spending was down 15 percent from the 1968 high, and universities dropped 8 percent below the maximum reached in 1972.

Government and industry support accounted for almost all applied research expenditures in 1976. The Federal share stood at 54 percent in 1976 while industry held 41 percent. These two sectors have shared the financing of applied research in roughly the same proportions since 1960. Constant dollar expenditures for applied research rose 5 percent between 1974 and 1976 from the Federal sector and 6 percent from universities and colleges. Spending from industry rose only 1 percent during the same period, but reached a new high in constant dollars for R&D.

Costs for development were shared equally by Government and industry in 1976. This has been the case since 1973, and represents a significant departure from 1960 when Government held 68 percent and industry provided 32 percent.

Constant dollar expenditures for development showed industry reaching a new peak in 1976. Federal constant dollar spending in 1976 stood 25 percent below the 1966 peak of $12.1 billion.

2-6
National R&D expenditures by character of work, 1960-76



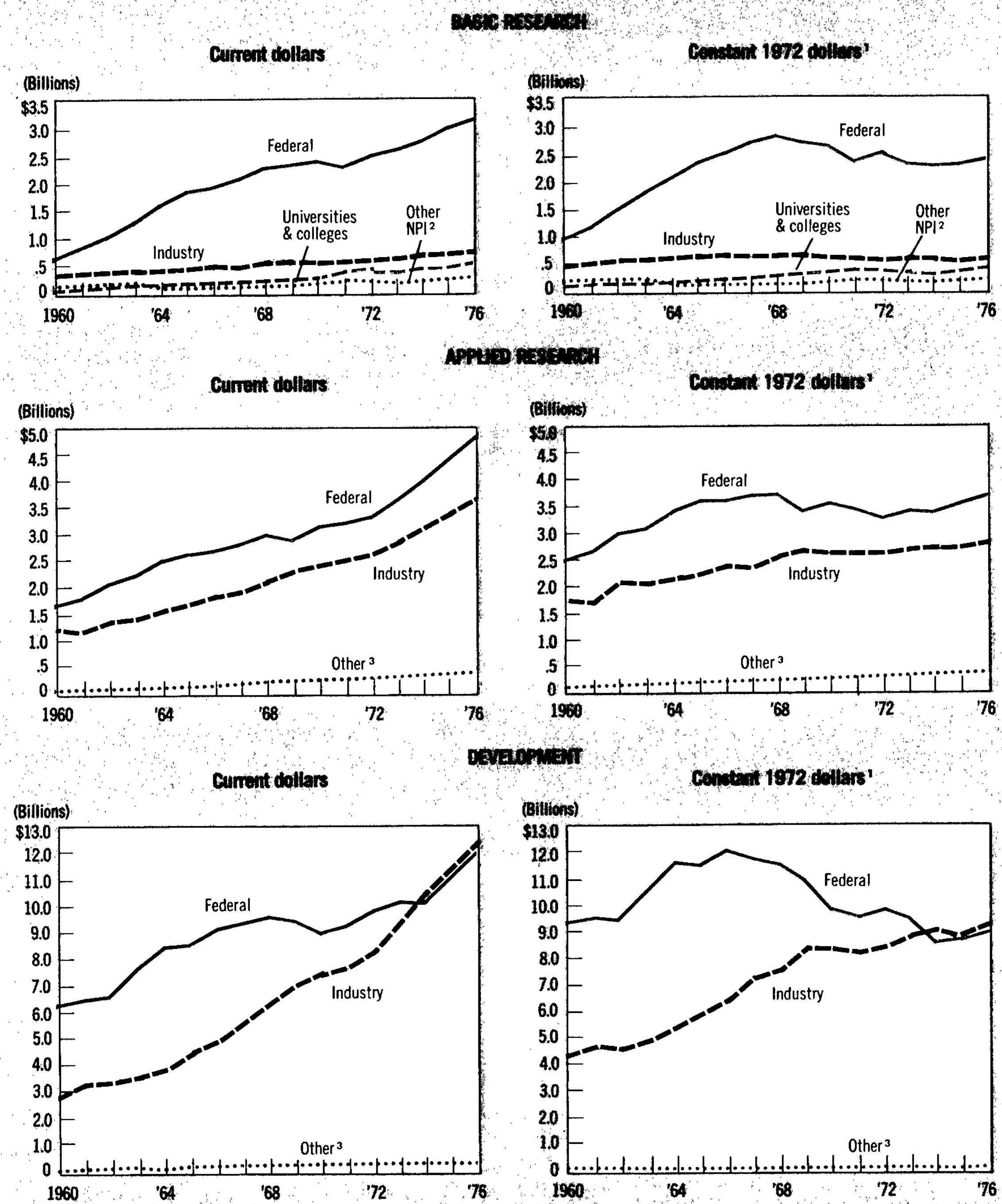
[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
NOTE: Estimates are shown for 1975 and 1976.
REFERENCE: Appendix Table 2-6.

FEDERALLY FUNDED R&D IN FUNCTIONAL AREAS

An assessment of Federal R&D funds provided to specific functional areas—such as defense, health, energy, and projects aimed at the expansion of basic scientific knowledge—can give insight into just how much dependence the Government places on R&D as a means for understanding and dealing with subjects that are of great national concern. What follows is a description of Federal resources in major R&D functional areas. To provide perspective, Federal R&D expenditures are compared with total Federal expenditures, Federal expenditures in principal functional areas toward which R&D is directed, and the R&D component of the "relatively controllable" portion of the Federal budget. This portion of the budget includes those items which are generally established by the current budgetary actions of either the Congress or Executive branch and which are not simply the playing out of previous legislative actions. The controllable portion excludes programs such as income security, medical benefits, interest on Treasury bonds and revenue sharing which may increase by law. These are considered uncontrollable because amounts required to support them are often open-ended and eligibility cannot be controlled by current actions. Since 1967 (the earliest year for which such data are available), the controllable portion of the Federal budget has been declining. In 1976 it stood at 42 percent,

2-7

National R&D expenditures by character of work and source of funds, 1960-76



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
[2] Other nonprofit institutions.
[3] Universities and colleges and other nonprofit institutions combined.
NOTE: Estimates are shown for 1975 and 1976.
REFERENCE: Appendix Tables 2-7, 2-8, and 2-9.

substantially lower than in 1967 when the controllable fraction was 65 percent.[10]

A marked decline in the percentage of total Federal outlays accounted for by R&D and R&D plant[11] began in 1965 and has continued into 1976. During this period, R&D expenditures have dropped to less than 6 percent from the 1965 level of almost 13 percent (Figure 2-8). Measured as a percentage of controllable outlays, R&D expenditures have dropped to the lowest level recorded since 1967. They comprised 13.5 percent of controllable outlays in 1976, about 3 percentage points below the 1967 peak.

Areas of federally funded R&D

Federal R&D falls into three main areas: national defense, space exploration, and "civilian" areas (such as energy, the environment and health). Figure 2-9 shows Federal obligations for these three major functions.[12]

Almost half of all 1976 Federal R&D obligations were for national defense. These costs reached an estimated $10.6 billion in 1976, a jump of 19 percent over 1974 spending. Constant dollar amounts were 3 percent above the 1974 level, but 17 percent below the peak year recorded in 1969.[13]

Spending for civilian R&D is largest in size after defense, and accounted for about 38 percent of all the 1976 Federal obligations for R&D. This area has shown remarkable growth. In current dollars, obligations grew 35 percent between 1974 and 1976. In addition, a constant dollar gain was registered in each year of the 1969-76 period. Overall, real dollar obligations in 1976 for civilian R&D advanced 48 percent above the 1969 level, and gained 18 percent between 1974 and 1976.

Obligations for the Nation's space program show a pattern almost directly opposite that for civilian areas. Constant dollar spending fell each year between 1969 and 1975, then rose 9 percent in 1976. The estimated 1976 real dollar figure of almost $2.2 billion was 50 percent below the peak reached in 1969, and grew only 1 percent between 1974 and 1976.

The 1976 R&D programs within these three broad categories are described briefly below. Items which accounted for significant portions of obligations in each area are discussed.

National Defense. Obligations for 1976 were directed to *missiles; other equipment; aircraft; defense-related atomic energy; ships and small craft; and military astronautics; ordnance and combat vehicles,* to name the major areas. The major components of the *missile* subfunction included Navy programs, such as the Trident submarine-launched missile system, the fleet ballistic missile system, and the sea-launched cruise missile. They also included Army programs such as the short-range air defense missile system, the SAM-D system, and improvements to Chaparral/Vulcan and Hawk, as well as the Site Defense program, and the ballistic missile advanced technology program. Air Force efforts included development of the air-launched cruise missile and the advanced ballistic missile technology program. *Other equipment* obligations covered, as an important component, work of the Air Force on the E-4, advanced airborne command post. Obligations for *aircraft and related equipment* included work by the Air Force on the B-1 bomber, the F-16 air combat fighter, and the advanced medium STOL transport. Navy projects included the air combat fighter, the air antisubmarine warfare system, and the airborne electronic warfare equipment program, while the Army was working on the utility tactical transport aircraft system (UTTAS) and advanced attack helicopter (AAH) programs. In the area of *defense-related atomic energy* (the responsibility of ERDA) laser fusion, weapons R&D and testing activities, and naval reactor development comprised the major programs for 1976. The subfunction *ships, small craft and related equipment* covered work by the Navy on the Trident submarine, surface effects ships, amphibious assault craft, hydrofoil craft, and surface antisubmarine warfare. Included under *military astronautics* were further development of the NAVSTAR global positionings system, work relating to warning and assessment of missile

[10] These estimates were obtained from *Federal Funds for Research, Development, and Other Scientific Activities,* National Science Foundation (NSF 75-334), page 4. For a more detailed discussion of "controllable" and "uncontrollable" components of the Federal budget, see *Setting National Priorities—The 1976 Budget* (Washington: Brookings Institution, 1975), pp. 190-230.

[11] R&D plant includes facilities and large items of fixed equipment. For a more detailed discussion of this topic see the section on R&D plant later in this chapter.

[12] Data are available regarding R&D by functional area only for Federal sources. The assignment of Federal R&D programs to these functional areas was performed under the supervision of the Government Studies Group, Division of Science Resources Studies, National Science Foundation.

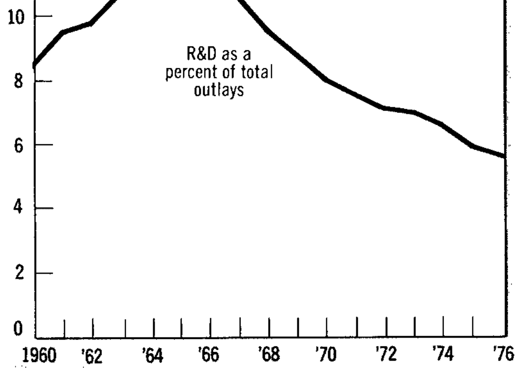
[13] Comparable data are not available for years prior to 1969.

attacks, a communications satellite system, and efforts toward use of the NASA space shuttle for launching military payloads. A new Army XM-1 tank and antitank capability were in development under the subfunction *ordnance, combat vehicles and related activities,* as were efforts toward improved mine systems for the Navy and the Air Force, and improved air delivered weapons, prototype laser weapons and guns for the Air Force A-10 close air support aircraft and air superiority aircraft.

Space Exploration. The major 1976 programs were categorized as *manned space flight; space sciences; space technology; and supporting space activities. Manned space flight* was the largest subfunction and had as its major focus the development of the NASA space shuttle. Additional programs were largely grouped under space flight operations, and these included space life sciences, mission systems and integration, and basic operational, engineering, technical and scientific activities in support of manned space flight. The second largest subfunction was *space sciences,* which had as its chief component the NASA lunar and planetary exploration program. Besides continued analysis of lunar material and data telemetered from the Moon, this broad program covered the Viking exploration of Mars, the development of Mariner spacecraft for the Jupiter-Saturn flyby missions, and development of an orbiter and probe spacecraft for launching to Venus. It also included plans for a Helios mission (co-sponsored by West Germany) to study the medium close to the Sun. Also included in the space sciences subfunction were a broad physics and astronomy program, covering stellar astronomy, solar physics investigations, high-energy astronomy and space physics investigations. *Space technology* covered efforts to provide a sound technology base for space programs. Work was involved with advancing technologies used in systems required to transport, protect, power, control, and communicate with NASA spacecraft and scientific instruments needed to achieve mission objectives. An ERDA space nuclear systems program and the NASA applications technology programs were also included under this subfunction. *Supporting space activities* were related to the operation of tracking and data acquisition networks.

2-8

Federal expenditures for R&D and R&D plant, as a percent of total Federal outlays, and as a percent of the relatively controllable portion of the Federal outlays, 1960-76



NOTE: Estimates are shown for 1976.
REFERENCE: Appendix Table 2-10.

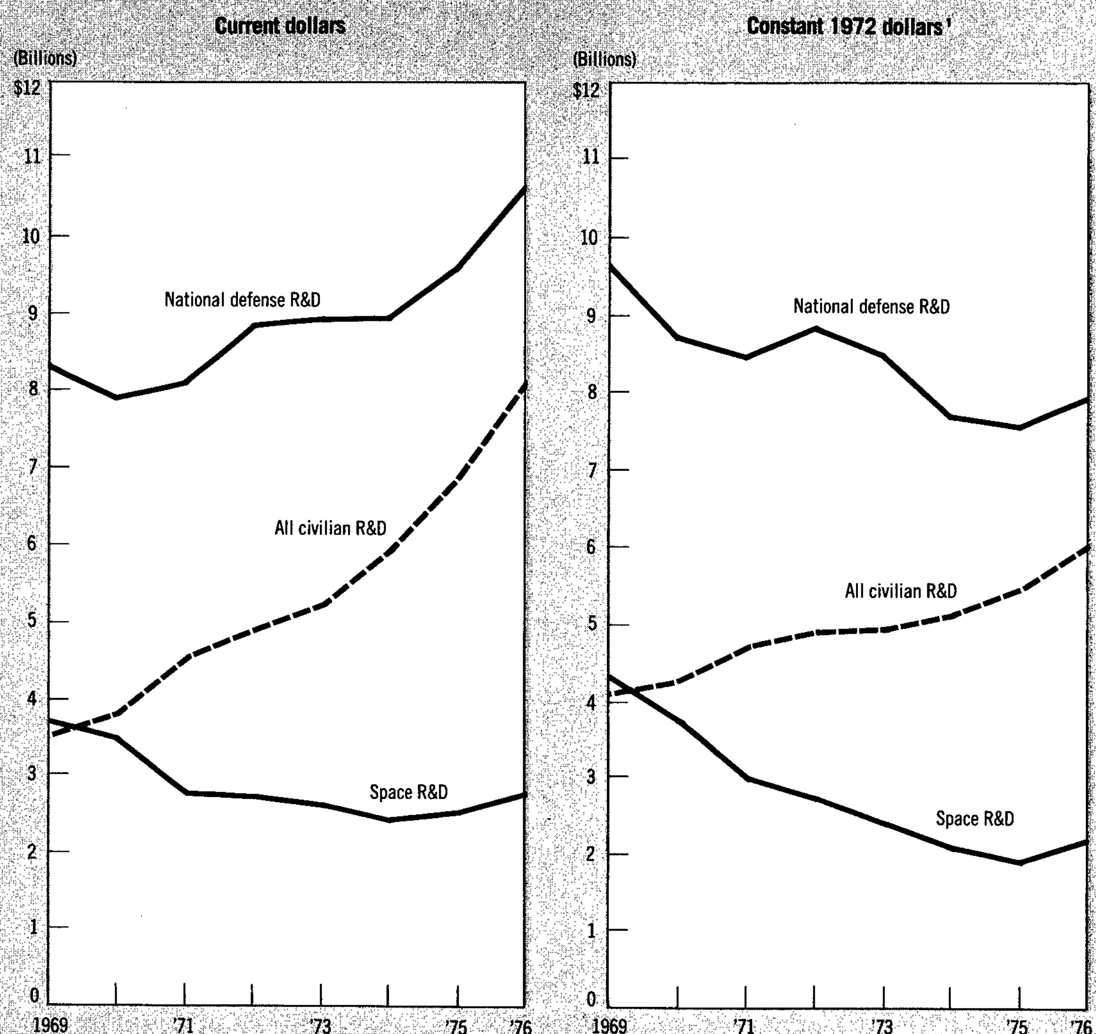
Civilian R&D (other than space). There are 13 areas that make up the civilian R&D category. The largest of these are health and energy, together accounting for almost one-half of all civilian R&D obligations in 1976 (Figure 2-10; see Appendix Table 2-11 for current dollar amounts). The recent rapid growth in R&D obligations to the civilian sector was due primarily to increased funding for energy. Measured in constant dollars, Federal obligations for energy R&D alone jumped 135 percent above the 1974 level, and 223 percent over funding provided in 1969. Spending for environmental efforts rose 23 percent above the 1974 figure in constant dollars. Although obligations for health R&D accounted for a substantial portion of the rise in civilian R&D spending since 1969, real dollar obligations have actually dropped by 2 percent since 1974.

The areas included in the civilian sector are listed here in Table 2-11 along with the proportion of funds going to each.

The following are brief descriptions of the largest civilian R&D areas.

(1) **Health** covered the subfunctions of *biomedical research; mental health; delivery of health care;* and *drug abuse prevention and rehabilitation.* The largest of these was *biomedical research,* accounting for 92 percent of all Federal health R&D obligations in 1976. It included activities of 11 components of the National Institutes of Health (HEW) which deal with specific chronic and communicable diseases and general medical sciences, as well as food and drug research and work on disease control. Biomedical research obligations have tended to grow steadily year after year. *Mental health* programs were the responsibility of the National Institute of Mental Health within HEW's Alcohol, Drug Abuse and Mental Health Administration (ADAMHA). In 1976 this activity represented 4 percent of the Federal R&D obligations for health. *Delivery of health care* consisted of a number of

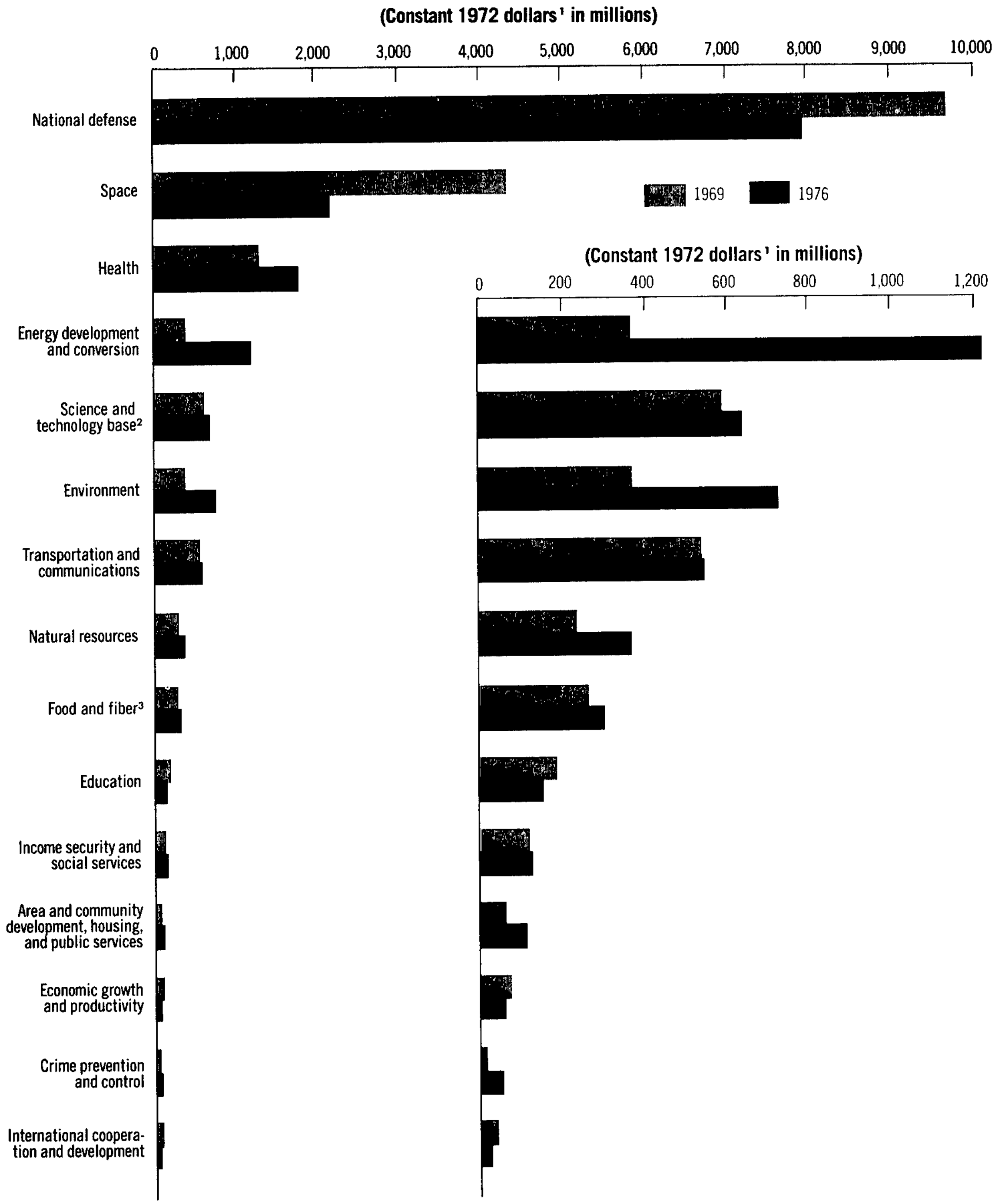
2-9
Federal obligations for R&D by major function, 1969-76



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
NOTE: Estimates are shown for 1975 and 1976.
REFERENCE: Appendix Table 2-11.

2-10

Federal obligations for R&D by function, 1969 and 1976 (est.)



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars. Current dollars are shown in Appendix Table 2-11.

[2] Basic research obligations which can be associated with the agencies' missions are not included here but are distributed across the appropriate functions.

[3] Food, fiber and other agricultural products is a new function category. Most programs under this activity were formerly included within the natural resources activity under a food subfunction.

REFERENCE: Appendix Table 2-11.

2-11. Distribution of Federal R&D obligations among civilian areas, 1969-76

R&D Function	Percent of the Federal R&D total				Percent of the civilian Federal R&D total			
	1969	1972	1974	1976	1969	1972	1974	1976
Health	7.2	9.6	12.0	11.0	31.7	32.4	35.0	29.2
Energy development and conversion	2.1	2.3	3.5	7.5	9.2	7.8	10.1	20.1
Environment	2.0	3.2	4.0	4.5	8.9	10.9	11.6	12.0
Science and technology base	3.3	3.6	4.0	4.0	14.4	12.3	11.6	10.6
Transportation and communications	2.9	3.7	4.0	3.3	12.9	12.6	11.7	8.8
Natural resources	1.3	2.1	2.0	2.3	5.7	7.2	5.7	6.2
Food and fiber[1]	1.4	1.8	1.7	1.9	6.3	5.9	4.9	5.0
Education	1.0	1.2	1.0	.9	4.4	3.9	2.9	2.3
Income security and social services	.6	.8	.8	.7	2.7	2.6	2.3	1.9
Area and community development, housing, and public services	.3	.6	.7	.6	1.4	2.1	2.0	1.7
Economic growth and productivity	.4	.4	.4	.4	1.6	1.2	1.1	1.0
Crime prevention and control	(2)	.2	.2	.3	.1	.5	.6	.8
International cooperation and development	.2	.2	.2	.2	.8	.6	.5	.4

[1] Food, fiber, and other agricultural products is a new function category. Most programs under this activity were formerly included within the natural resources activity under a food subfunction.

[2] Less than .05 percent.

REFERENCE: Appendix Table 2-11.

HEW programs with widely different missions, including the health services research and evaluation program, of the Health Resources Administration (HRA), emergency medical services programs and the maternal and child health services programs of the Health Services Administration (HSA), and the national health statistics program of HRA. They accounted for 2 percent of the 1976 health R&D total, compared with 5 percent in 1969. The last category of health-related activities is that of *drug abuse prevention and rehabilitation*, which included the drug abuse and alcoholism research activities of ADAMHA, and the drug abuse program of the Veterans Administration. This category made up 2 percent of the 1976 health total. Current dollar funding in 1976 fell 6 percent below 1975, primarily because of the termination of the Special Action Office of Drug Abuse Prevention.

(2) **Energy Development and Conversion** was divided into subfunctions related to specific aspects of the energy problem, and these are *nuclear energy; fossil energy; solar, geothermal and advanced energy systems; energy conservation;* and *other*. In 1976, *nuclear energy* activities related primarily to ERDA research on fission and fusion power, nuclear materials development and advanced isotope separation techniques. The Nuclear Regulatory Commission conducted reactor safety research and was engaged in nonreactor confirmatory research. Under the subfunction of *fossil fuels* were grouped several ERDA programs, including those dealing with coal utilization, petroleum, and natural gas; and of these the coal program was by far the largest. Research on *solar, geothermal and advanced energy systems* formed another subfunction, with most work under the broad heading sponsored by ERDA. *Energy conservation* programs covered ERDA work on electric energy systems and energy storage. It also included studies aimed at improving efficiency, and various conservation programs sponsored by TVA, DOT, and NSF. In 1976, the chief R&D effort conducted under the category of *other* energy was a NASA program devoted to implementing energy activities that require aerospace technology; this was accomplished through support to other agencies, State and local governments, and others.

(3) **Environment** included the areas of *environmental health and safety; pollution control and environmental protection;* and *understanding, describing, and predicting the environment. Environmental health and safety* was the largest of these

in 1976, making up two-fifths of the entire environment function. The ERDA biomedical and environmental research program was the largest one under this subcategory, followed by Bureau of Mines health and safety research. Within the *pollution control and environmental protection* subfunction—one-third of the environment function—the largest program area consisted of a group of energy-related environmental programs conducted by EPA. Also included were EPA water quality and air quality research and development, environmental quality monitoring projects by NASA, nuclear materials security and safeguard programs by ERDA, and various NSF, TVA and DOT programs. *Understanding, describing, and predicting the environment* accounted for over one-fourth of the 1976 environment total. Under this subfunction were found a wide variety of environmental satellite projects supported by NASA and related to weather, ocean, and pollution monitoring, and environmental service efforts sponsored by the National Oceanic and Atmospheric Administration within the Department of Commerce.

(4) **Science and Technology Base** covered support of basic and applied research in the various fields of science, where the chief purpose is to support research as a source of national scientific strength rather than to support agency mission objectives. Basic research obligations which can be associated with the agencies' missions are not included in "Science and Technology Base." Almost one-half of this function in 1976 was represented by NSF Scientific Research Project Support and more than one-third by ERDA's physical research and basic energy programs. Also included were NSF support to the National Research Centers, and basic research support by the Smithsonian Institution, and the National Bureau of Standards.

(5) **Transportation and Communication** was a function that incorporated research and development in *air, ground, water,* and *multimodal* transportation subfunction areas in addition to work in *communications.* The *air* subfunction was the largest, accounting for almost three-fifths of the total in 1976. NASA's aeronautical research and technology program made up most of this subfunction and more than two-fifths of the total function. *Ground* transportation encompassed development and demonstration programs of DOT's Urban Mass Transportation Administration and R&D efforts of DOT's Federal Railroad Administration, National Highway Traffic Safety Administration, and Federal Highway Administration. *Water* transportation R&D efforts included those of the Maritime Administration (Commerce), and of the Coast Guard (DOT). The *multimodal* subfunction was entirely made up of a program of the Office of the Secretary, DOT, to stimulate industry to advance transportation technology and universities to further research. Under the *communications* subfunction the chief activity was the NASA communications satellite program.

(6) **Natural Resources** includes R&D activities aimed at improving utilization of the Nation's *mineral, water, land, recreation,* and *multi-resources.* Included in the *mineral* subfunction were geologic and mineral resources surveys of the Geological Survey (Interior), mining technology, and metallurgy research of the Bureau of Mines (Interior). Studies of *water* resources covered water resources investigations of the Geological Survey as well as research sponsorship by the Office of Water Research and Technology (Interior). The *land* subfunction included forest insect and disease research and timber management research of the Forest Service (USDA), as well as cooperative forestry research sponsored by the Cooperative State Research Service. In 1976 the *recreation* subfunction consisted of several programs of the Fish and Wildlife Service (Interior) dealing with wildlife resources, wildlife restoration and fishery resources, and a few other smaller programs of the Forest Service and TVA. Also included under natural resources was a *multiresource* subfunction that covered all NASA earth resources surveys, investigations of the use and improvement of soil, water and air by the Agricultural Research Service (USDA), and the Sea Grant program of NOAA.

(7) **Food and Fiber** reflected work of the Cooperative State Research Service (USDA), plant and animal production research of the Agricultural Research Service, ocean fisheries and living marine resources research of the National Oceanic and Atmospheric Administration (Commerce), and various USDA marketing and distribution efforts.

(8) The **Education** function was entirely composed of HEW and NSF programs in 1976. These included programs of the Office of Education (HEW) and the National Institute of Education (HEW) while the NSF effort involved science education improvement.

RESEARCH FACILITIES

Effective R&D programs cannot be undertaken unless adequate facilities are available. An examination of resources available for R&D laboratories can provide information about factors which have a direct impact on the ability to perform R&D activities and serve as another indicator of the health of the U.S. R&D effort.

R&D plant

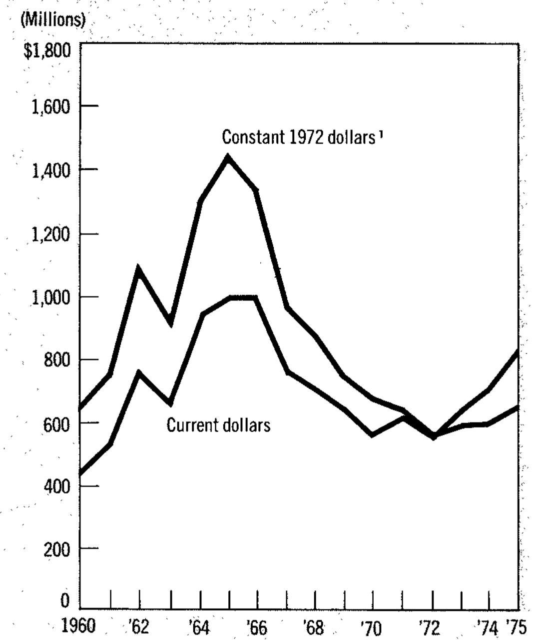
Resources in this area go for the acquisition, construction, and major repair of R&D facilities, as well as for the purchase of large fixed equipment such as reactors, wind tunnels, and radio telescopes. Data are available for only one source of support for R&D plant—the Federal Government. Funds from this source, however, are believed to represent a large part of the total investment in this area, although the relative size of the Federal role may vary among different sectors.

Federal expenditures for R&D plant are shown in Figure 2-12. The rapid growth of expenditures during the early 1960's was due almost entirely to the expansion of intramural facilities of the National Aeronautics and Space Administration (NASA); the decline in later years reflects, largely, the completion of these facilities. The up-turn in expenditures after 1972 was produced by increased spending on the part of the Energy Research and Development Administration (ERDA, formerly the Atomic Energy Commission), NASA, and the Department of Health, Education, and Welfare; funds from these agencies were directed in the main to industry and Federal intramural facilities.

In recent years, over three-fourths of the Federal support for R&D plant has been allocated to two sectors—Federal intramural laboratories and industry (Figure 2-13). The intramural laboratories received 42 percent of the funds in 1975, industry 36 percent, Federally Funded Research and Development Centers (FFRDC's) administered by universities 16 percent, universities and colleges 4 percent, and other nonprofit institutions 2 percent.

2-12

Federal expenditures for R&D plant, 1960-75



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

REFERENCE: Appendix Table 2-12.

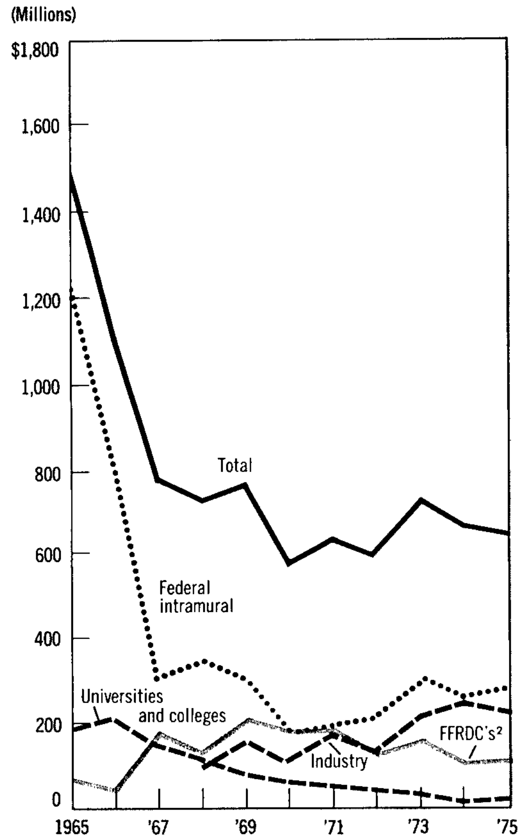
Federal support for R&D plant is also shown in Figure 2-14, which presents the relationship between Federal funds for R&D plant by selected performer as a percent of Federal obligations for R&D and R&D plant for that performing sector. The early rise and later decline in this ratio for the Federal intramural laboratories was due mainly to a like pattern of change in NASA funds for R&D plant. The ratio for university FFRDC's fluctuated from year to year, with the figure for 1975 standing at 12 percent. In universities and colleges, on the other hand, the ratio decreased steadily from a peak in 1966 and 1967 of 11 percent, to a low of 1 percent in 1974 and 1975.

SCIENTIFIC AND TECHNICAL INFORMATION

One of the most critical components of research and development act)vities is the gathering and dissemination of information.

2-13

Federal obligations for R&D plant in constant dollars[1], by performer, 1965-75



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

[2] Federally Funded Research and Development Centers administered by universities.

REFERENCE: Appendix Table 2-13.

Efficient communication procedures and systems may not only prevent duplication of effort, but may also speed up the time between R&D and its application.[14]

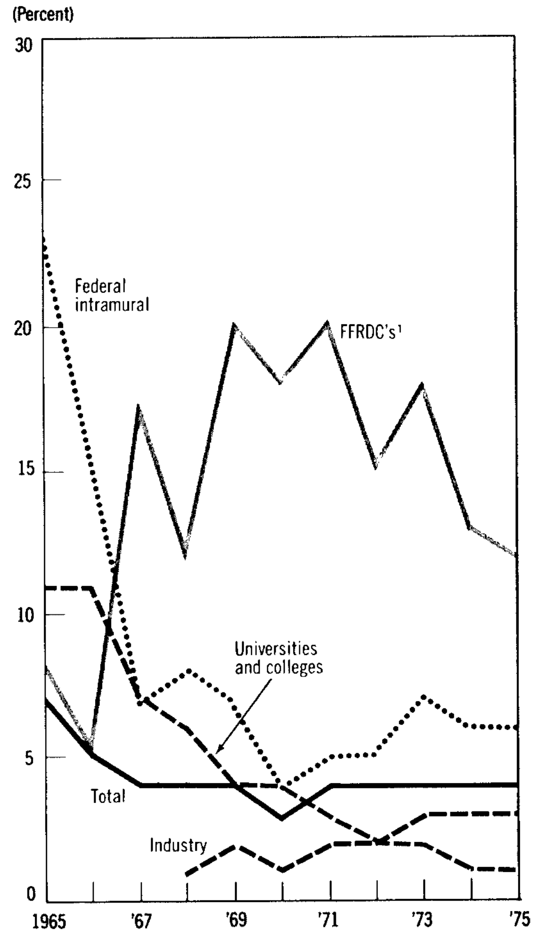
In virtually all areas of R&D, substantial resources are devoted to a wide variety of information handling efforts. However, the exact amount spent by all sectors of the economy on these activities is not known. Estimates have been made which indicate that total national resources committed to S&TI activities reached $9.4 billion in 1975.[15]

Some information is available on funds provided by the Federal Government. Its spending, measured in constant dollars, peaked during 1968 but dropped 26 percent below that level in

[14] For information on Federal programs aimed at disseminating and transferring scientific and technical knowledge to potential users in the private and public sector see *Federal Technology Transfer Directory of Programs, Resources, Contact Points*, Federal Council for Science and Technology, Committee on Domestic Technology Transfer, 1975.

2-14

Federal obligations for R&D plant as a percent of Federal obligations for total R&D including plant, by selected performer, 1965-75



[1] Federally Funded Research and Development Centers administered by universities and colleges.

REFERENCE: Appendix Table 2-14.

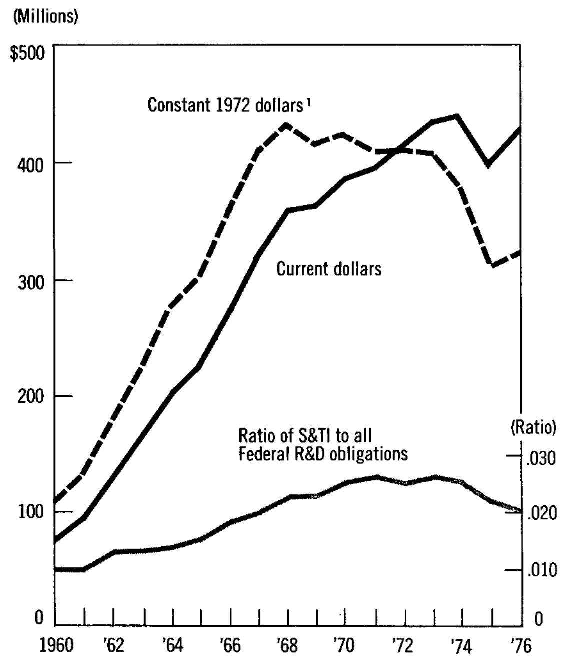
[15] *Statistical Indicators of Scientific and Technical Communication, 1960-1980* (Rockville, Md.: King Research, Inc., Center for Quantitative Sciences, 1976), p. 13.

1976 (Figure 2-15). Another index, the ratio of total scientific and technical information (S&TI) obligations to Federal R&D, was .020 in 1976, down considerably from the .025-.026 level maintained throughout the early 1970's.

About two-thirds of all Federal support for S&TI activities in 1976 was provided by DOD, HEW, and the Department of Commerce (Figure 2-16). Obligations by the latter were the largest, for an estimated total of $108 million—a large portion of which goes to support programs such as the National Technical Information Service. Next in size with $96 million was DOD which supplies information through the Defense Documentation Center, followed by HEW which supports a variety of programs, a major one being the National Library of Medicine.

2-15

Federal obligations for scientific and technical information activities compared with total Federal R&D obligations, 1960-76



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1976.

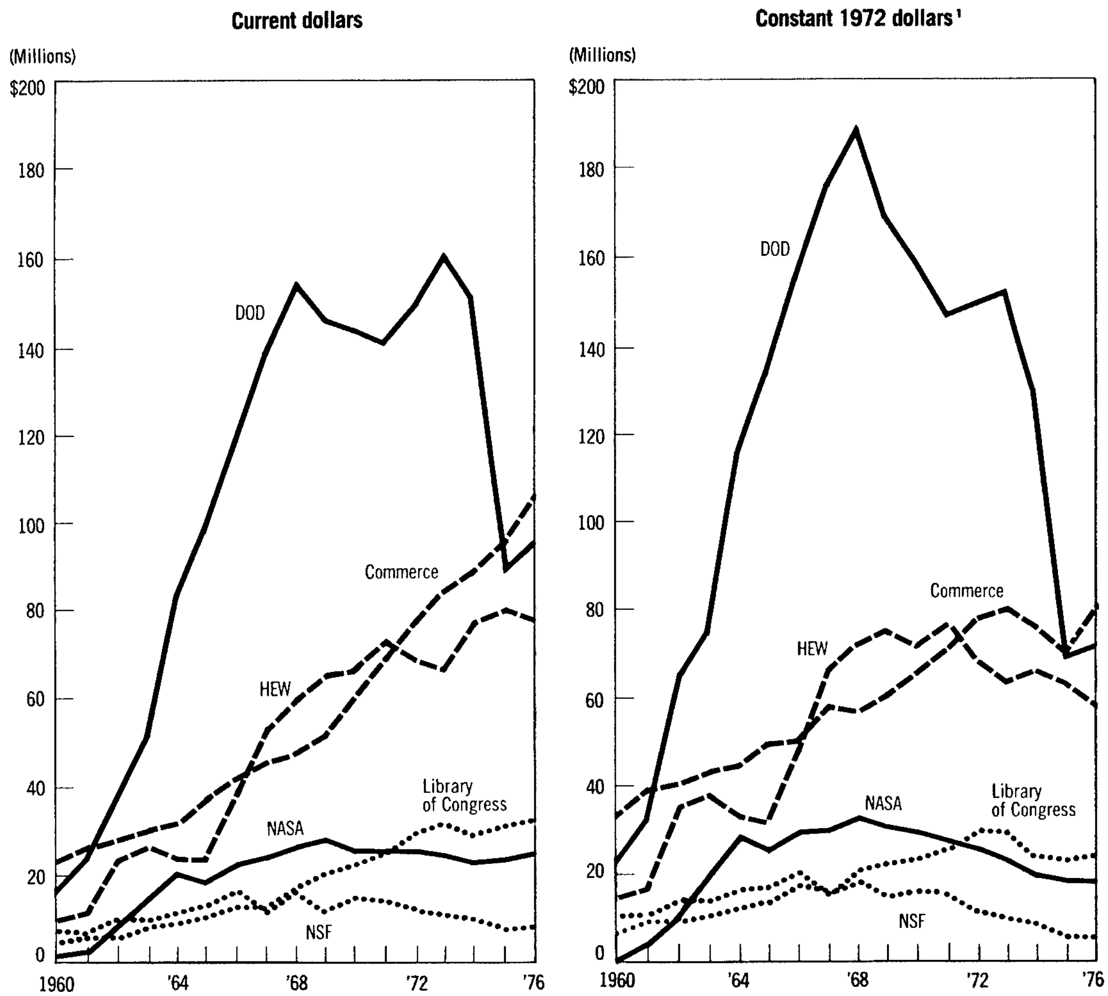
REFERENCE: Appendix Table 2-15.

The S&TI activities supported by Federal agencies cover many different areas, but can be generally classified into four different categories: (1) publication and distribution; (2) documentation, reference and information services; (3) symposia and audiovisual media; and (4) R&D in information sciences, documentation and information systems, techniques and devices. Obligations for documentation, reference and information services accounted for the largest amount in 1976 for an estimated total of $192 million (Figure 2-17). Publication and distribution costs were next with $138 million. Together, these two areas accounted for over three-fourths of the total. Obligations for symposia and audiovisual media totaled $26 million while the remaining category had $75 million.

The often reported "information explosion" is commonly thought of as a product of increased scientific and technical activity in the Nation. Attempts to quantify the magnitude of this expansion and to assess its status include evaluations of the number of scientific and technical articles published during certain time periods. The rate at which U.S. authors have published articles in U.S. scientific and technical journals has risen dramatically since 1960 (Figure 2-18). Between 1960 and 1975 the number of articles appearing in such journals increased by 154 percent, or at an average annual rate of 6.4 percent. These estimates must be viewed with caution because of difficulties involved in defining those publications which are considered scientific and technical, and because sources for such information often include journals which are no longer in publication. Nevertheless, it is possible to view these general trends in journal literature production as a possible indicator of science activity.

2-16

Federal obligations for scientific and technical information activities by selected agency, 1960-76



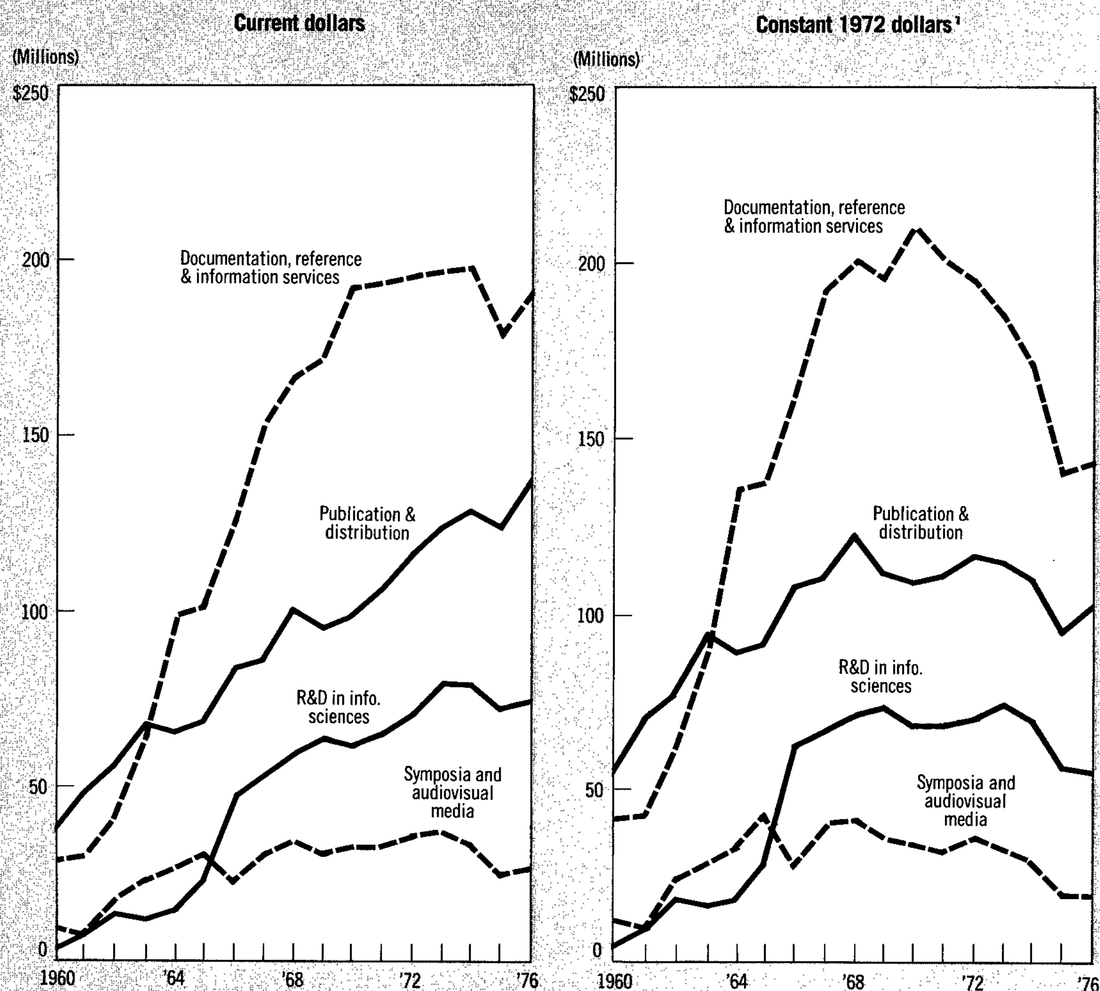
[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1976.

REFERENCE: Appendix Table 2-16.

2-17

Federal obligations for scientific and technical information activities by type of activity, 1960-76



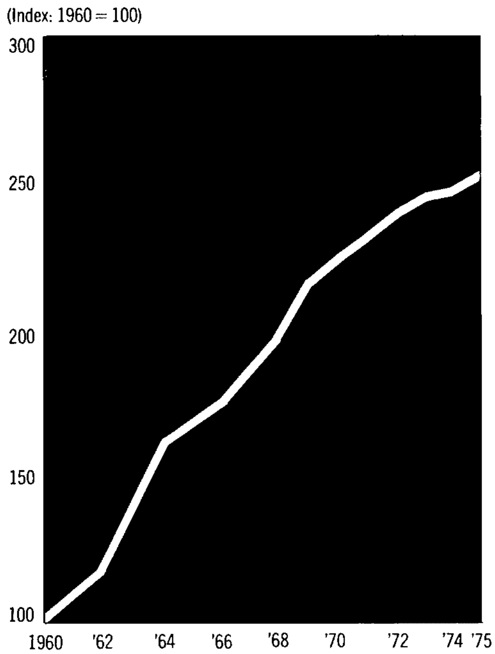
[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1976.

REFERENCE: Appendix Table 2-17.

2-18

Scientific and technical articles published by U. S. authors in U. S. primary journals, 1960-75



NOTE: Data for 1961, 1963, 1965, and 1967 are not available. Estimates are shown for 1975.

REFERENCE: Appendix Table 2-18.

Chapter 3

Resources for Basic Research

Resources For Basic Research

INDICATOR HIGHLIGHTS

- National spending, in current dollars, for basic research climbed substantially since 1960, and rose to a new high in 1976; in constant dollars however, estimated expenditures in 1976 advanced approximately 2 percent above the 1975 level, but remained nearly 11 percent below the peak year of 1968.
- Among performers of basic research, more than half of the Nation's expenditures were accounted for by universities and colleges in 1976, compared to a 37 percent share by this sector in 1960. Industry held an estimated 16 percent (half of its 1960 share) in 1976; the Federal Government also held 16 percent in 1976.
- The source of most support for basic research was the Federal Government in 1976, as it has been in past years. The Federal share has amounted to 68 percent of the total since 1971, compared with approximately 60 percent in 1960; the share of support provided by industry has remained stable at approximately 15 percent throughout the 1970's, in sharp contrast to the 28 percent share this sector provided in 1960.
- In constant dollars, estimated Federal and industrial support for basic research in 1976 was 15 percent below the peak levels which each had reached in 1968. Real dollar support by each of these sectors has remained at about the same level between 1974 and 1976.
- Six agencies—HEW, NSF, ERDA, DOD, NASA and USDA—obligated over 90 percent of Federal basic research funds in 1976. Current dollar obligations by these six agencies have increased 32 percent in the period 1967-76.
- Federal obligations for basic research in the life sciences, environmental sciences, engineering, and social sciences, reached their highest current dollar levels in 1976. However, constant dollar obligations in all fields were lower than in previous years.
- In current dollars, 1976 basic research expenditures by universities and colleges advanced an estimated 21 percent above the level reached in 1974. Constant dollar expenditures grew 5 percent during this period. However, even with this 5 percent growth, expenditures in the latter year were roughly equal to the level reached in 1969.
- In constant dollars, Federal spending for academic basic research peaked in 1968, but real dollar expenditures for 1976 remained an estimated 10 percent below that peak year. Federal sources provide the largest share of expenditures for basic research in universities and colleges. Between 1970 and 1976 this share has accounted for approximately 70 percent of the total.
- Nearly all Federal obligations for academic basic research in 1976 were provided by only six agencies: HEW, NSF, DOD, ERDA, NASA and USDA. In most cases, NSF and one other agency provided over three-fourths of the support in a given field of science and engineering.
- Federal intramural laboratories were responsible for an estimated 15 percent of total national expenditures for basic research in 1976, and 22 percent of all federally supported basic research for that year. Constant dollar funding in 1976 for basic research in these laboratories rose some 2 percent above 1975 levels, but was still below the 1969 peak year.
- Industrial performers were responsible for an estimated 16 percent of the Nation's total basic research expenditures in 1976. In current dollars, these expenditures reached a new high in 1976. However, constant dollar expenditures were comparable to those of 1972.
- The university sector was the largest producer of research reports in 1975 for 11 selected fields. This sector accounted for an average 73 percent of the articles. Government and industry each accounted for 11 percent, while nonprofit institutions had 4 percent.

It is through basic research that man strives for new knowledge of himself and nature. Basic research programs are not driven by practical need or potential application. Rather, they are fueled by the desire to advance the existing state of scientific understanding itself. Its practitioners range from teams of scientists working in large facilities, to individuals with little or no research equipment. Basic research is also international in nature, joining the activities of scientists from many countries.[1]

Although curiosity is often cited as the prime motive of the individual scientist for performing research, it often happens that the information derived from basic research programs leads to practical applications of substantial value to the Nation. These benefits are extremely difficult to quantify. However, it has been estimated that advances in knowledge are the largest single source of long-term growth of total economic output.[2] According to this author, new knowledge has accounted for one-third or more of the total growth in output in the United States since World War II.[3] Included in his definition of knowledge are those things usually defined as technical knowledge concerning the physical properties of things and how to make, combine or use them in a physical sense. In addition, the definition includes managerial knowledge or knowledge of business organizations and of management techniques. Knowledge originating both in the United States and abroad, and knowledge obtained through large-scale organized research, individual research workers and inventors, and by simple observation and experience, as well as any other techniques, are included.

Even with such estimates of the contribution to growth made by new knowledge in general, there is no method for relating the cost of basic research in particular with its total returns—intellectual, social and economic. However, the many and varied uses of basic research suggest that the benefits are substantial, particularly in comparison with the relatively small investment involved.

Estimates of the costs of performing basic research, however, are somewhat easier to obtain, and it is clear that the level of basic research activity in the Nation (and perhaps the potential contributions to society made by such activities) is a function of the fiscal resources devoted to the effort. Therefore, indicators of the state of basic research presented in this chapter consist largely of the financial resources committed by various sectors to basic research. Such "input" indicators provide information on National expenditures for basic research, the extent of research performed in universities and other sectors, and trends in expenditures for basic research in the various fields of science. One "output" indicator is also presented: an analysis of publication rates of scientific research articles produced by different sectors in major fields of science.

This chapter's indicators are deficient in a number of major aspects. They do not encompass substantive aspects of basic research, such as advances in knowledge achieved in the various scientific disciplines. The indicators, furthermore, do not identify the wide applications made of the results of this research. Nor do they represent the economic and social returns from the varied uses made of its cumulative findings. The present indicators, in addition, do not include measures of the effectiveness, or productivity, of the research activity.

Besides these deficiencies, there are other limitations in regard to the data used for the present indicators. There is, for example, uncertainty regarding the precision with which "basic" research can be distinguished from "applied" research. A particular research effort may be identified as basic or applied, depending on whether the classification is made by the sponsor of the research or by the organization or individual performing it. Furthermore, differences among sectors in the assignment of costs to basic research make it difficult to compare expenditures and the magnitude of research efforts among the sectors. Industrial firms, for example, include in their reported expenditures for basic research an annual depreciation cost of the facilities used in the research; universities and Federal laboratories do not. The construction costs of large, Government-financed research facilities such as

[1] For further discussion of international aspects of science, see the chapter entitled, "International Indicators of Science and Technology" in this report.

[2] Edward F. Denison, *Accounting for United States Economic Growth, 1929-1969* (Washington, D.C.: Brookings Institution, 1974), pp. 79, 112.

[3] The growth accounting methods used to make this estimate involved the use of time series data in which factors of input were related to factors of output for specific time periods. The contribution of a number of identifiable determinants of output per unit of input were also measured. The output remaining when other factors were accounted for comprised a residual which was considered to be accounted for by advances in knowledge.

the Fermi National Accelerator Laboratory are not included as basic research expenditures. However, each sector's trends are consistently defined over time.

NATIONAL RESOURCES FOR BASIC RESEARCH

Total national expenditures for basic research have risen steadily between 1960 and 1976. In current dollars, spending grew from $1.2 billion to an estimate of almost $4.8 billion during that period (Figure 3-1). However, forces of inflation have cut sharply into this increase. In real dollars, basic research expenditures for 1976 rose only 2 percent over 1975, to $3.5 billion—roughly equal to those of 1965 and 11 percent below the peak year of 1968.

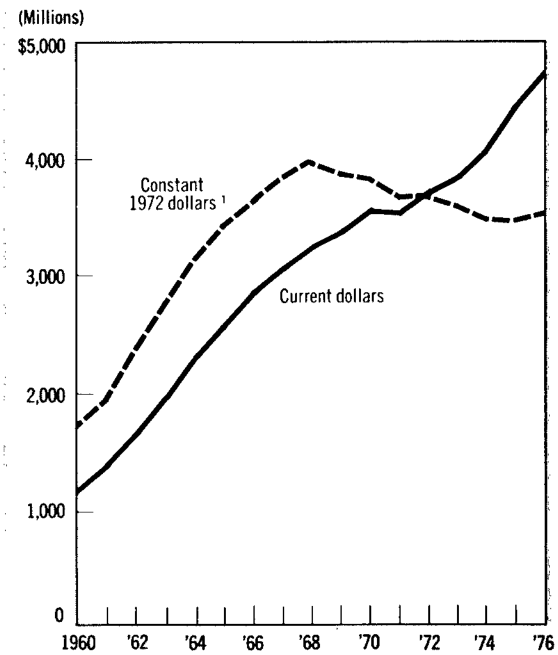
About 12 percent of the Nation's total R&D expenditures in 1976 were for basic research. This percentage has remained about the same since 1965.[4]

Expenditures by Performer

Private industry, Federal laboratories, universities and colleges (and the Federally Funded Research and Development Centers they administer), and other nonprofit institutions are the major sectors which perform basic research. Because these sectors have differing missions and purposes, two different definitions of basic research have been used for obtaining the data reported here. For all but the industry sector, the definition of basic research stresses that such activity be directed toward increases of knowledge in science with the primary aim *of the investigator* being ". . .a fuller knowledge or understanding of the subject under study, rather than a practical application thereof." For the industrial sector, to take account of an individual company's commercial goals, basic research is defined as ". . .original investigations for the advancement of scientific knowledge. . .which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company."

Universities and colleges are the primary means by which the United States conducts its basic research effort. These institutions account

3-1
Basic research expenditures, 1960-76



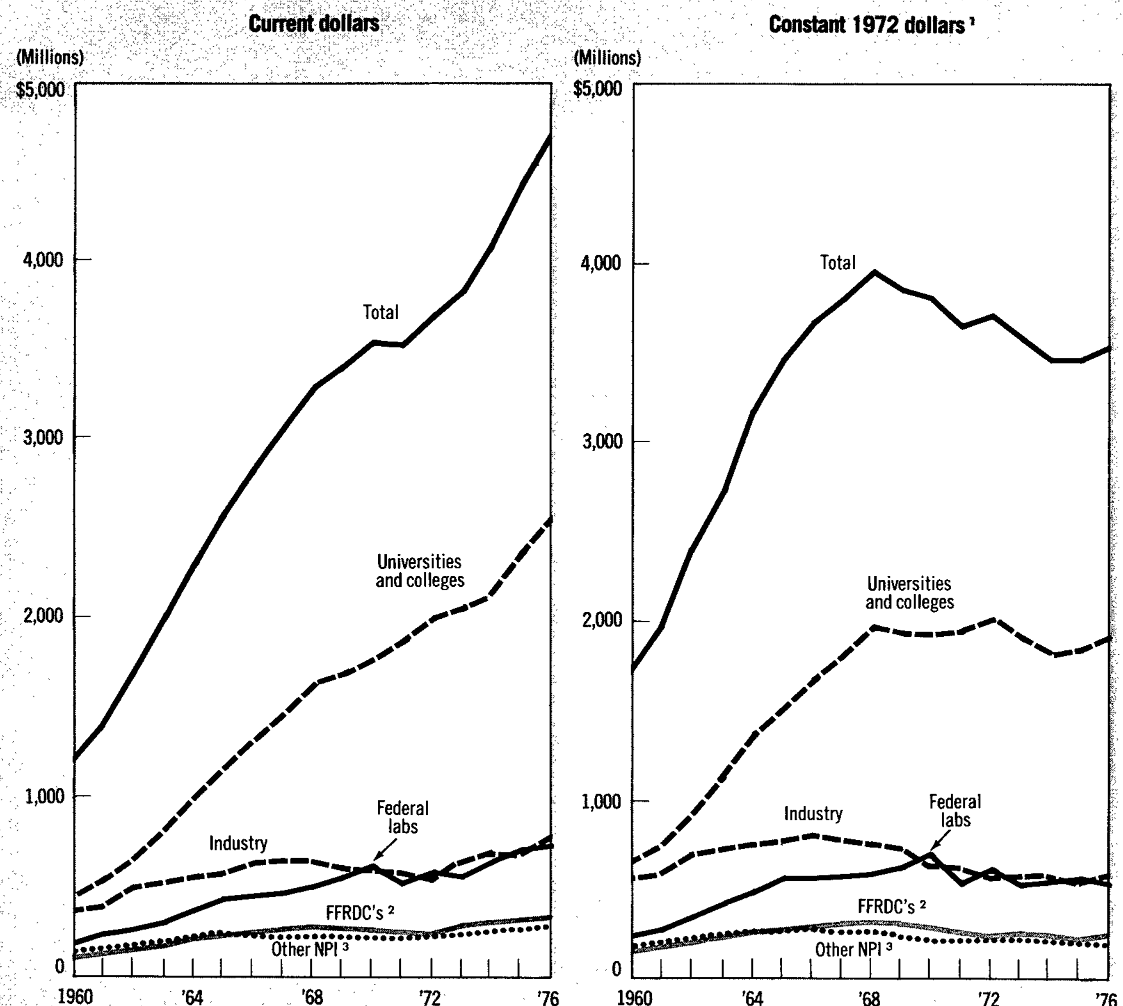
[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
NOTE: Estimates are shown for 1975 and 1976.
REFERENCE: Appendix Table 3-1.

for the majority of expenditures for such work. In 1976, their estimated spending for basic research amounted to $2.6 billion, or 55 percent of the total (Figure 3-2), compared to a 37 percent share in 1960. The percentage of funds spent by industry on basic research has also shifted a similar amount over the period 1960-76, dropping from 32 percent to 16 percent. Proportions of basic research expenditures held by the other performing sectors have remained fairly constant since 1960. In 1976 the Federal Government spent 16 percent, FFRDC's accounted for 7 percent, and other nonprofit organizations, 6 percent.

Constant dollar expenditures for basic research in each performing sector were lower in 1976 than in some previous year of peak spending. However, spending by universities and colleges showed the smallest relative loss. Expenditures in 1976 were 4 percent below the peak year of 1972. In all other performing sectors, 1976 levels were between 21 percent and 29 percent below earlier peak years.

[4] *National Patterns of R&D Resources*, National Science Foundation (NSF 76-310), p. 4. See also Appendix Table 2-6.

3-2
Basic research expenditures by performer, 1960-76



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
[2] Federally Funded Research and Development Centers administered by universities.
[3] Other nonprofit institutions.
NOTE: Estimates are shown for 1975 and 1976.
REFERENCE: Appendix Table 3-2.

The only performer experiencing a constant dollar gain above expenditures for 1974 was the universities and colleges, rising over 5 percent by 1976.

Basic Research Support by Source of Funds

Performers of basic research receive their support from the Federal Government, industry, universities, and nonprofit organizations. Of these four sources, Federal sponsors have usually provided the largest share (see Appendix Table 3-3). Since the mid-1960's, this share has amounted to between 68 percent and 70 percent of the total. Industry has provided about 15 percent throughout the 1970's, while universities and colleges and other nonprofit organizations provided approximately 11 percent and 6 percent, respectively, since 1960. In

real dollars, the only sponsors which provided a peak level of support in 1976 were the nonprofit organizations (Figure 3-3). In all other sectors, funding in 1976 remained below an earlier peak. Federal and industrial constant dollar support were 15 percent below the peak levels which each had reached in 1968.

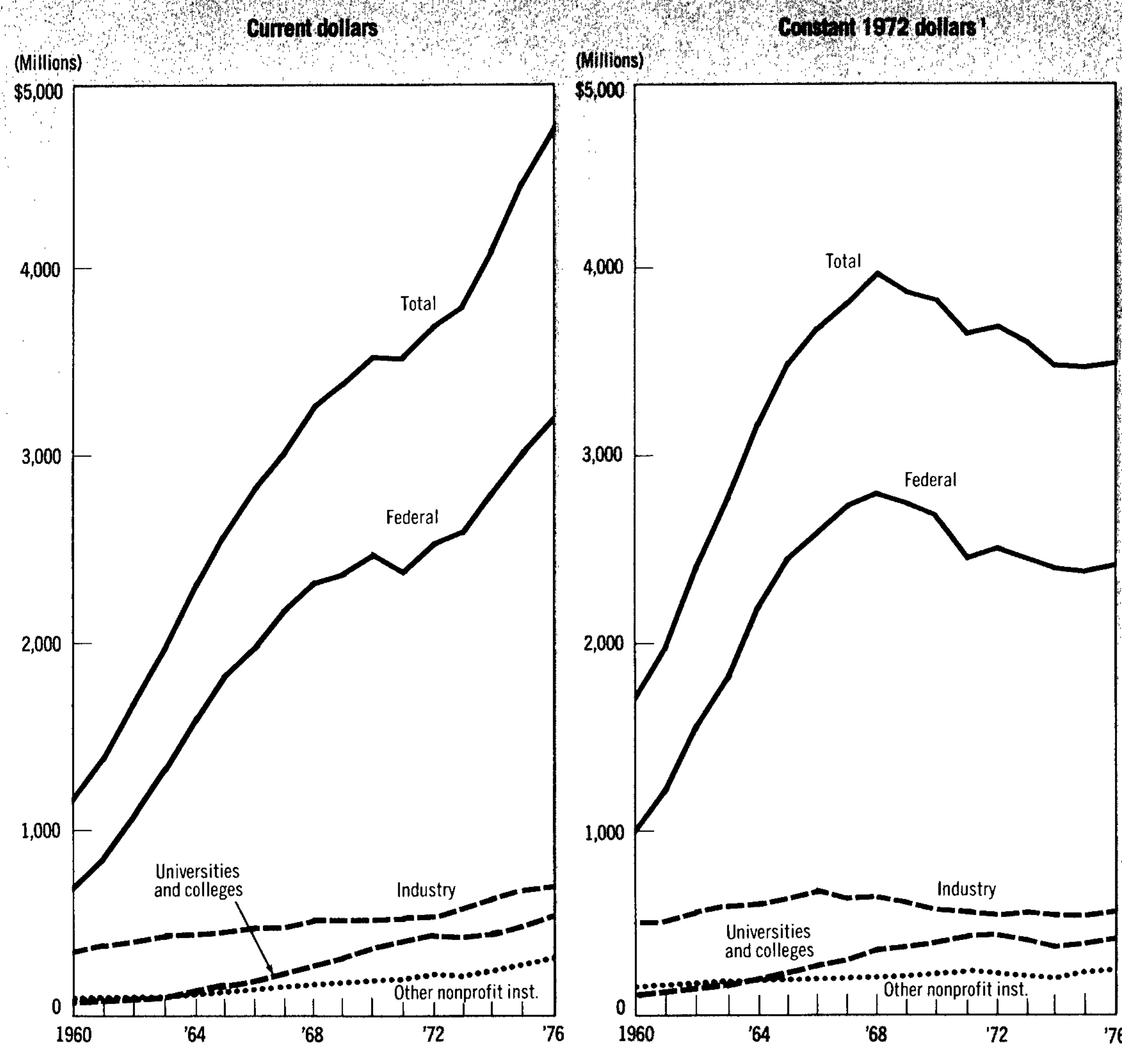
Between 1974 and 1976, real dollar support by Federal and industrial sources remained at about the same level. Funding by universities and colleges[5] rose by 6 percent in the period 1974-76, while the support by nonprofit organizations advanced 9 percent.

Federal Support of Basic Research

Since World War II, when the critical importance of basic research in advancing the health

[5] Includes funds from State and local governments, as well as from the universities and colleges themselves.

3-3
Basic research expenditures by source, 1960-76



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1975 and 1976.

REFERENCE: Appendix Table 3-3.

and welfare of the Nation was first recognized, the Federal Government has assumed a major responsibility for its support.

The basic research effort has laid the foundations on which advances in the country's defense, economy, health, education, and its cultural and intellectual life are built. Such research is supported by many Federal agencies as a means of fulfilling their missions. HEW obligated more funds than any other agency for support of basic research in 1976. Two HEW components—the National Institutes of Health (NIH) and the Alcohol, Drug Abuse and Mental Health Administration (ADAMHA)—accounted for some 98 percent of all HEW's estimated basic research obligations in that year. An indicator of the importance which HEW attaches to basic research in areas relating to health sciences can be seen largely from obligations by these two components. In 1976, the NIH obligated 90 percent of its basic research funds for work in life sciences. ADAMHA obligated 56 percent of its funds for life sciences and 41 percent for psychology and social sciences.[6] In contrast, all other components of HEW which reported obligations for basic research in 1976 (Health Services Administration, the National Institute of Education, the Social Security Administration, and the Office of the Secretary) supported a total of only 2 percent of the agency's basic research obligations.

One agency, the National Science Foundation, was created for the express purpose of supporting scientific research and strengthening the Nation's capability in science. It is one of six agencies which devotes a significant amount of its resources to support of basic research. Together, the following agencies (Table 3-4) accounted for over 90 percent of all Federal obligations[7] for basic research in Fiscal Year 1976.[8]

3-4. Distribution of total Federal obligations for basic research by agency, 1976

Federal agency	Percent
All agencies	100
Department of Health, Education, and Welfare (HEW)	29
National Science Foundation (NSF)	23
Energy Research and Development Administration (ERDA)	12
Department of Defense (DOD)	11
National Aeronautics and Space Administration (NASA)	10
Department of Agriculture (USDA)	8
All other agencies	7

REFERENCE: Appendix Table 3-5.

Basic research and total agency R&D. Each of these Federal agencies has a need to emphasize programs of basic research to a different degree. Figure 3-5 shows the percentages of their total R&D programs which are reported as basic research. The ratio of basic research to total Federal R&D obligations for all agencies combined has remained between 10 percent and 12 percent during those years for which data are available.

The largest ratio was held by the NSF, as would be expected in view of its designated role in the support of basic research. In 1976, NSF obligated 85 percent of its R&D funds for basic research compared to the high of 92 percent reached in earlier years. This represents an upturn from a low of 75 percent reached in 1974, which had resulted from the impact of the support of new and largely applied research programs such as Research Applied to National Needs.

Proportionally, the USDA was the next largest supporter of basic research in 1976, obligating some 37 percent of its R&D funds for this purpose, followed by HEW with 26 percent, ERDA with 10 percent, NASA, 7 percent, and DOD, 3 percent.

Overall, current dollar obligations for basic research by these six agencies have increased 32 percent between 1967 and 1976, for an average annual rate of approximately 3 percent. During

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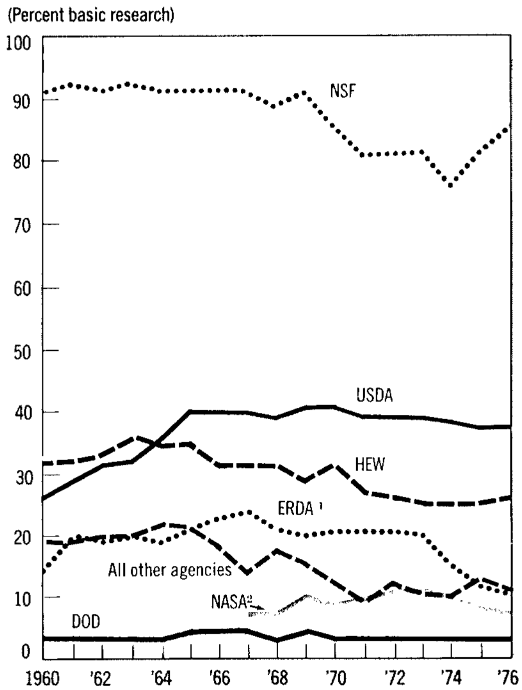
[6] *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977*, Vol. XXV, Detailed Statistical Tables, National Science Foundation (NSF 76-315), pp. 48, 54.

[7] Federal obligations for basic research may differ from federally provided expenditures in the same year for a number of reasons. A sector which performs research, for example, may report expenditures for research projects which it regards as "basic research", whereas the Federal agency providing the support may report the same projects as consisting of "applied research". In addition, obligations made in a given year may actually extend over several later years in terms of the availability of the funds for expenditure. Moreover, the withholding of obligated funds may have produced discrepancies between obligations and reported expenditures.

[8] *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977*, Vol. XXV, Detailed Statistical Tables, National Science Foundation (NSF 76-315), p. 147.

3-5

Federal obligations for basic research as a percent of each agency's R&D obligations by agency, 1960-76



[1] Includes only the Atomic Energy Commission prior to 1974.
[2] Data for NASA are not available for most years prior to 1967.
NOTE: Estimates are shown for 1976.
REFERENCE: Appendix Table 3-4.

the same period, their total R&D obligations grew 25 percent, at an average annual rate of about 2.4 percent. Between 1973 and 1976, however, their basic research obligations grew 15 percent while those of total R&D increased 28 percent.

Basic research obligations. Figure 3-6 shows basic research obligations in both current and constant dollars for each of the six major agencies as well as all other agencies combined. In 1976, each agency increased obligations in current dollars for basic research programs. However, measured in constant dollars, only HEW and NSF reached new highs in 1976.

The relative support in 1976 given to basic research in the principal scientific disciplines by each agency were:[9]

HEW. Life sciences received approximately 85 percent of the basic research obligations. Support for physical sciences amounted to 5 percent, while psychology and social sciences received 4 percent and 3 percent respectively.

NSF. The largest percentage of funds, some 28 percent, went for basic research in the physical sciences, while over 26 percent was obligated for environmental sciences. Life sciences accounted for almost 19 percent, and engineering received 12 percent.

ERDA. Approximately 82 percent of basic research obligations were for work in physical sciences, while about 15 percent funded engineering studies.

DOD. In defense agencies, engineering accounted for almost 30 percent of all obligations for basic research. Environmental sciences received 24 percent, physical sciences 22 percent, and the life sciences 11 percent.

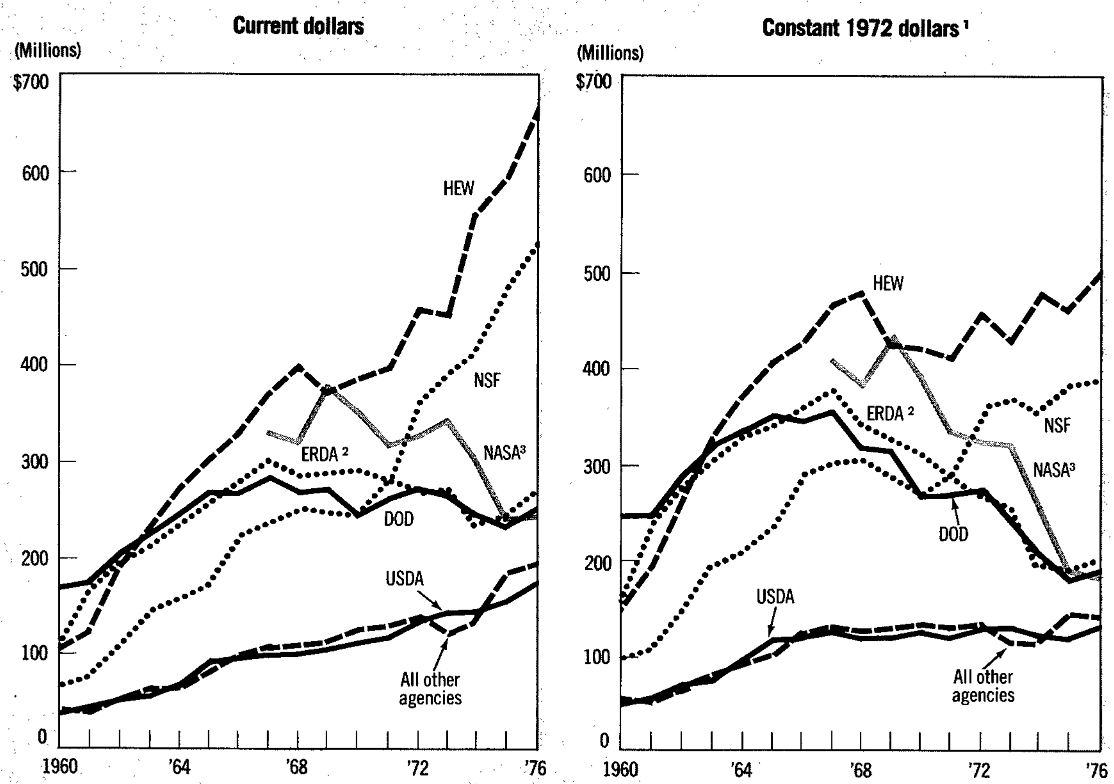
NASA. The physical sciences made up 61 percent of the space agency's basic research obligations, while environmental sciences received 17 percent. Basic research obligations for engineering accounted for almost 16 percent.

USDA. The majority of the Department of Agriculture's basic research obligations went for life sciences and physical sciences, receiving 71 percent and 13 percent, respectively.

Substantial shifts have occurred in the proportion of total Federal basic research obligations by the agencies between 1967 and 1976. The percentage supplied by HEW has risen from 21 percent to 28 percent while the NSF share of the Federal total jumped from 14 percent to almost 23 percent during this period. Obligations by the Department of Defense fell from 16 percent to about 11 percent. This decline may be due, in part, to the "Mansfield Amendment" which restricted DOD to the funding of basic research only if related directly to its mission.

[9] From *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977*, Vol. XXV, Detailed Statistical Tables, (NSF 76-315), p. 48.

3-6
Federal obligations for basic research by agency, 1960-76



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
[2] Included only the Atomic Energy Commission prior to 1974.
[3] Data for NASA are not available for most years prior to 1967.
NOTE: Estimates are shown for 1976.
REFERENCE: Appendix Table 3-5.

In the case of NASA, recent changes were made in the classification of its programs by character of work. Most of the major NASA projects are now categorized entirely as development since they largely generate outer space hardware and related technology. In former years substantial portions of these projects were classified as basic research or applied research. Data from those years for which reclassifications were made show a decline in the agency's share of basic research obligations from a high of 21 percent in 1969 to 10 percent in 1976.

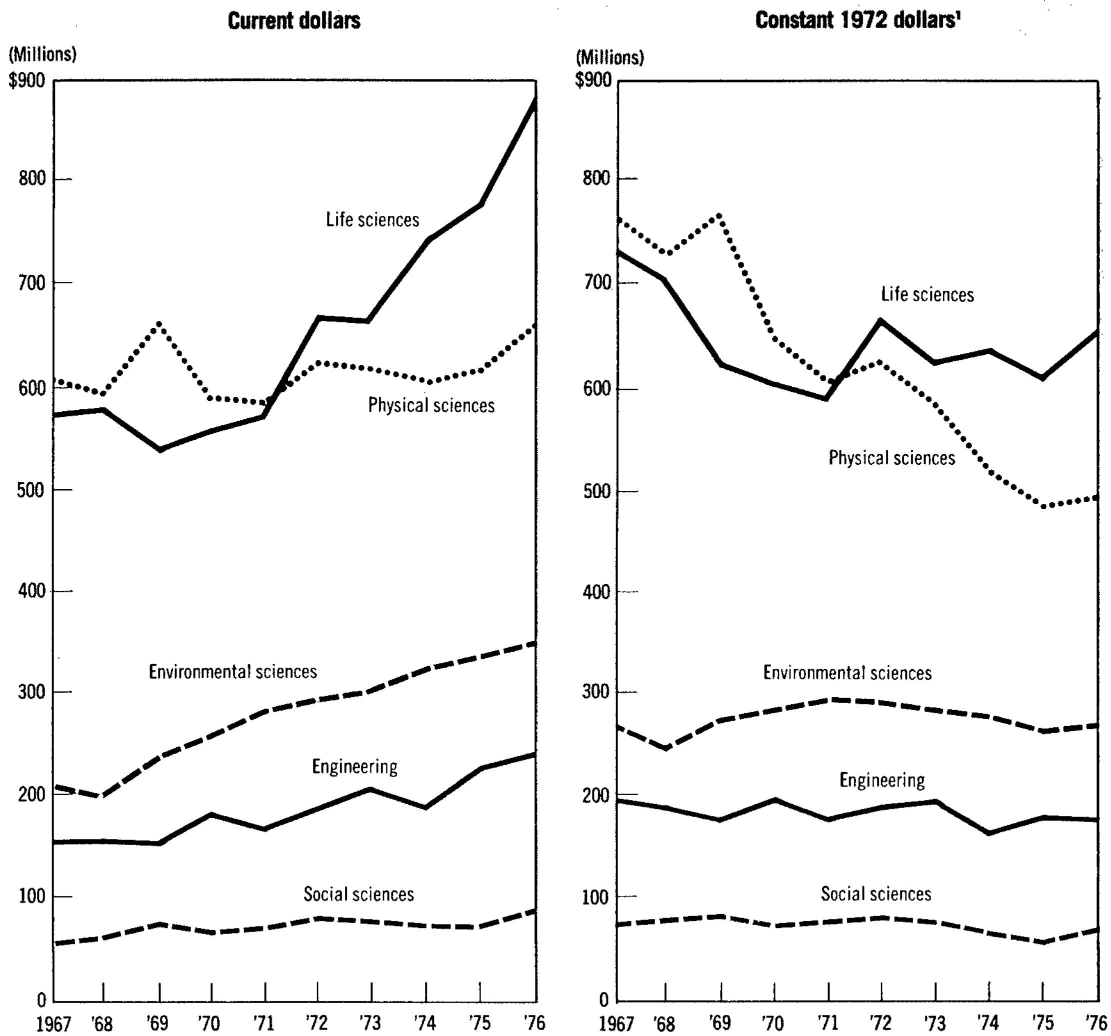
The share of Federal basic research obligations held by ERDA has also declined somewhat, dropping from 17 percent in 1967 to 12 percent in 1976, while those by USDA have remained fairly constant, moving only from 6 percent to about 8 percent during this period.

Basic research obligations in scientific areas. The scientific areas in which most federally supported basic research is conducted are presented in Figure 3-7. The five fields shown accounted for almost 95 percent of all Federal basic research obligations in 1976.[10]

[10] See Appendix Table 3-6 for detailed data for other disciplines and Appendix Table 3-7 for a listing of the scientific disciplines encompassed in these fields.

3-7

Federal obligations for basic research by selected field of science, 1967-76



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1976.

REFERENCE: Appendix Tables 3-6 and 3-7.

In current dollars, estimated obligations for basic research in life sciences, environmental sciences, engineering and social sciences reached their highest levels in 1976. However, constant dollar figures show that in all areas, basic research obligations were lower in 1976 than in some previous year. The field of psychology showed the greatest real dollar decline of all, falling by 50 percent between 1967 and 1976. Constant dollar obligations for basic research in mathematical and computer sciences also fell sharply, dropping by 44 percent during the same period.

The distribution of basic research obligations among these fields has not changed considerably since 1967. The greatest change occurred in the physical sciences where the share of total

obligations dropped from 35 percent in 1967 to 28 percent in 1976. Shares held by life sciences and environmental sciences increased by 4 percent and 3 percent respectively during this period, while those for the other fields were within approximately 1 percentage point of the fraction they held in 1967.

BASIC RESEARCH IN UNIVERSITIES AND COLLEGES

The principal performers of basic research in the United States are universities and colleges. They accounted for 55 percent of such work in 1976, spending an estimated total of $2.6 billion (Figure 3-2). This is in sharp contrast to 1953 when universities and colleges accounted for only 26 percent of basic research expenditures, industry held 35 percent, and the Federal intramural effort accounted for 24 percent.[11] With increased Federal support of basic research, the fraction of the total going to universities and colleges grew more rapidly than that for industrial and Federal intramural sectors. In 1976, funds for industrial and Federal intramural sectors had declined to 16 percent each. There was little change in the share of basic research expenditures held by the nonprofit organizations and the university FFRDC's, with each accounting for some 6 percent to 8 percent of basic research expenditures since the mid-1960's (Appendix Table 3-2).

The important role universities and colleges play in the performance of basic research is also reflected by the number of articles which their scientists and engineers contribute to the literature. In 1974, U.S. authors from this sector produced almost three-fourths of all articles appearing in U.S. scientific and technical journals (Appendix Table 3-22), and two-thirds of another larger sample of all U.S. authors' world publications.[12]

Basic research in universities and colleges ranges from the efforts of individual scientists and engineers to those of large research teams which often are organized around the use of unique equipment and facilities. Most of the research takes place in universities which have graduate-level programs offering doctorate degrees; these institutions reported 98 percent of all academic basic research expenditures in 1975.[13]

In current dollars, estimated total basic research expenditures by universities and colleges reached the highest point ever in 1976, approximately 21 percent above the level reached in 1974.[14] In addition, constant dollar expenditures have also grown in both 1975 and 1976, reaching $1.9 billion in the latter year. This represents a growth of 5 percent over expenditures in 1974. However, the constant dollar level reached in 1976 was roughly equal to spending levels of 1969. The recent increases in expenditures for academic basic research were due largely to increased funding by the Federal Government. Expenditures in constant dollars from this source rose by 4 percent between 1974 and 1976, thus accounting for most of the 5 percent total expenditure increase in that period.

Sources of Funds for Academic Basic Research

The Federal Government provides the largest amount of support for basic research to universities and colleges (Figure 3-8). In current dollars, Federal expenditures have risen steadily in the period 1960 to 1976. When measured in constant dollars, spending for academic basic research by the Federal Government peaked in 1968, then fell substantially, dropping steadily through 1974. In 1975 real expenditures rose slightly, then climbed again in 1976; however, the estimated 1976 level remained 10 percent below that of the 1968 peak year.

The Federal share of expenditures for basic research in universities has declined somewhat from the 75 to 77 percent portion held during the mid to late 1960's. Between 1970 and 1976, Federal expenditures have accounted for approximately 70 percent to 72 percent of the total. The share of expenditures by "all other

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[11] Calculated from *National Patterns of R&D Resources, 1953-1976*, National Science Foundation (NSF 76-310), pp. 22-23.

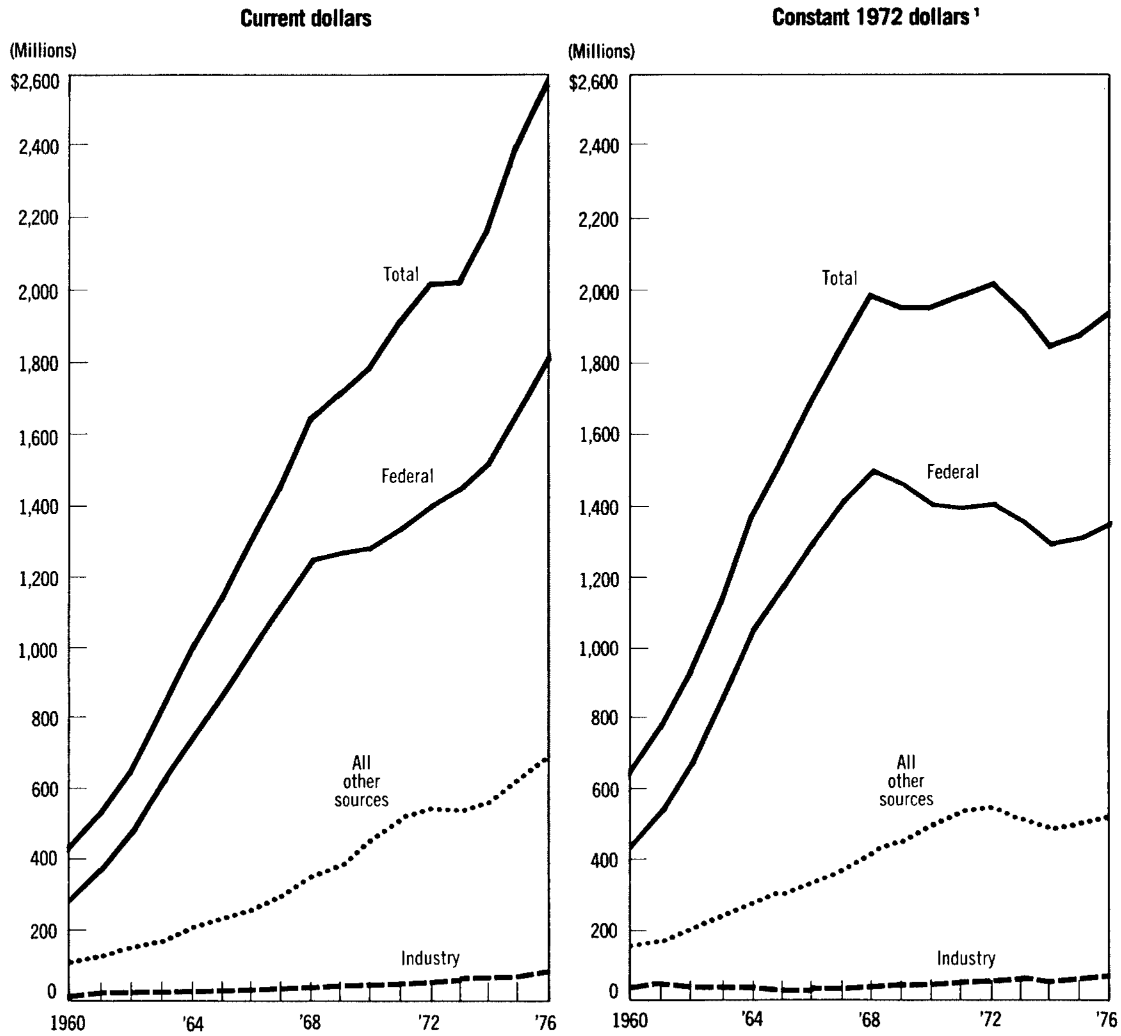
[12] Computer Horizons, Inc., unpublished data.

[13] *Expenditures for Scientific and Engineering Activities at Universities and Colleges, FY 1975*, Detailed Statistical Tables, National Science Foundation (NSF 76-316), calculated from data on pp. 3, 5.

[14] These expenditure data are for basic research which has been sponsored by other agencies and organizations, as well as basic research supported by an institution's own funds which it allocates to separately organized institutes, divisions, or specific basic research projects. They do not include the expenditures for research-teaching assignments of the faculty (departmental research). Expenditures associated with FFRDC's administered by universities are treated later in this chapter.

3-8

Basic research expenditures in universities and colleges by source, 1960-76



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1975 and 1976.

See Appendix Table 3-8.

sources"[15] had risen to 27 percent in 1976, up from the 20 percent share held in 1965. Less than 3 percent of the basic research expenditures at colleges and universities were provided by industry in 1976.

[15] Such sources include universities and colleges themselves, State and local governments, and other non-profit organizations.

Support by Federal Agencies

The six Federal agencies mentioned earlier accounted for 97 percent of total Federal obligations to universities and colleges for basic research in 1976. The NSF and HEW together provided almost 74 percent of all such obligations.

Individual Federal agencies differ greatly in the proportion of their total obligations for basic

research which they direct to universities and colleges (Table 3-9). Of the six agencies referred to earlier, NSF and HEW allocated the largest fraction of their total basic research obligations to educational institutions in 1976 (77 and 66 percent respectively), followed by DOD with 42 percent, USDA with 28 percent, ERDA with 23 percent, and NASA, 22 percent.

Figure 3-10 illustrates the support provided to these fields of science and engineering by the six agencies which obligate the majority of basic research funds to universities and colleges. It also shows that in most cases, for a given field of science and engineering, NSF and one other agency provided the bulk of support in 1976. For example, more than 80 percent of the obligations for work in engineering were provided by NSF and DOD in 1976, and some 90 percent of obligations for basic research in the life sciences were accounted for by NSF and HEW. In chemistry, almost 80 percent was provided by NSF and HEW, while NSF and DOD obligated nearly 90 percent of funds for environmental science basic research in 1976. Obligations for physics were provided primarily by NSF and ERDA, accounting for some 84 percent of all basic research funds in that field. The NSF and DOD obligated 90 percent of basic research funds for mathematics, while NSF, HEW, and USDA were primarily responsible for nearly all support given for basic research in social sciences.

In any of the fields mentioned above, support to universities and colleges by NSF in 1976 was

3-9. Basic research obligations to universities and colleges as a percent of total basic research obligations, by agency and by field,[1] 1974-76

Agency		All fields	Life sciences	Physical sciences	Environmental sciences	Engineering	Social sciences
NSF	1974	74	85	74	60	81	85
	1975	78	87	77	65	84	85
	1976 (est.)	77	86	77	63	85	82
HEW	1974	69	69	84	—	72	64
	1975	66	66	85	—	79	53
	1976 (est.)	66	66	85	—	79	46
DOD	1974	40	25	33	37	43	12
	1975	40	40	36	40	38	15
	1976 (est.)	42	34	38	38	42	4
USDA	1974	26	27	9	31	16	55
	1975	28	28	10	27	20	67
	1976 (est.)	28	28	10	26	15	66
ERDA	1974	24	40	23	77	31	—
	1975	23	—	24	23	19	—
	1976 (est.)	23	—	23	18	19	—
NASA	1974	18	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]
	1975	27	53	22	38	23	100
	1976 (est.)	22	32	19	30	18	100
Six-agency total	1974	49	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]
	1975	53	62	39	53	46	70
	1976 (est.)	52	61	39	50	45	67

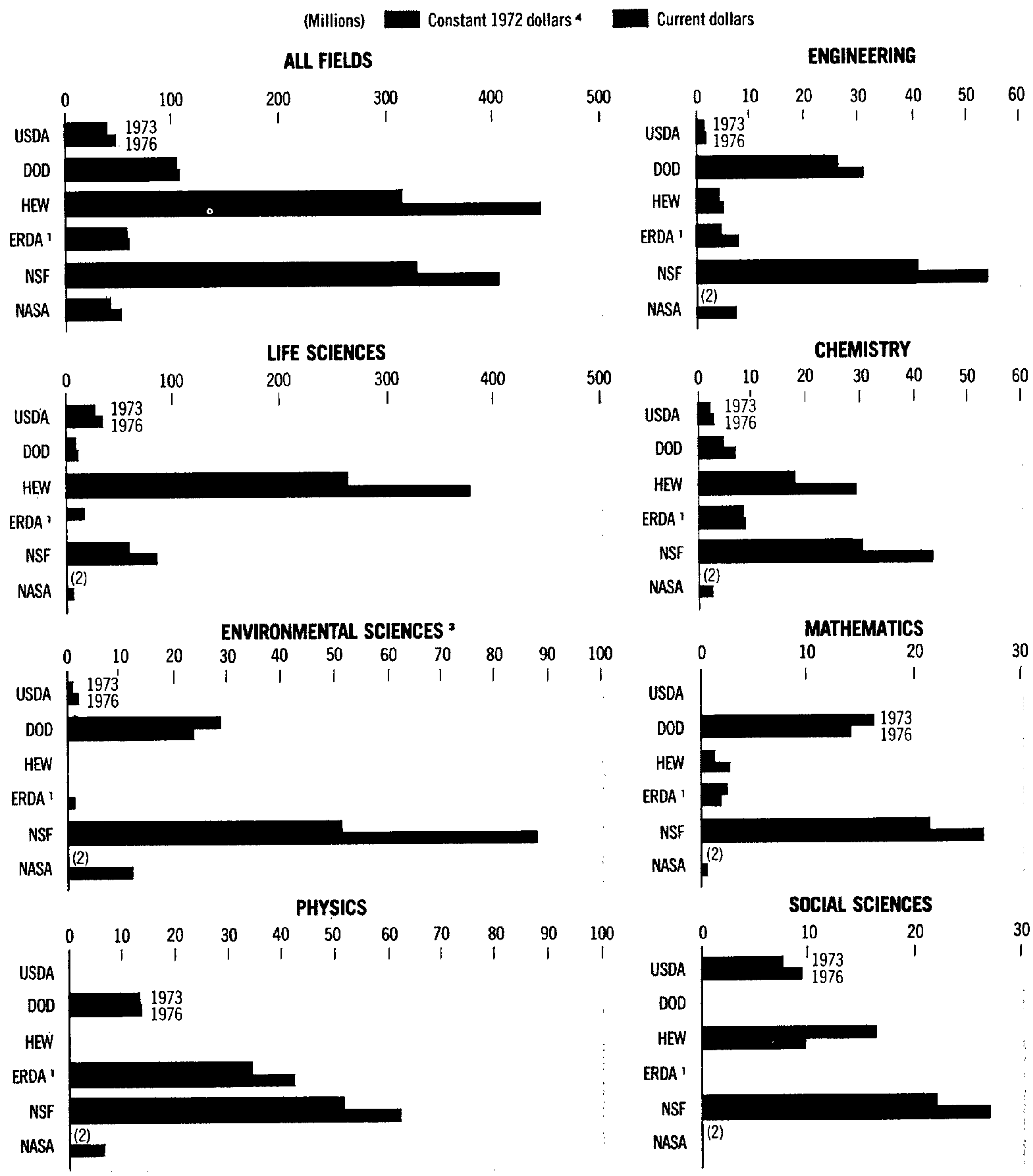
[1]Each field and the total were calculated separately.

[2] Data by field for NASA for 1974 are not available. Although changes were made in what NASA considers basic research, obligations for all prior years have not yet been adjusted to reflect the changes in reporting.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977,* Vol. XXV (NSF 76-315), earlier volumes, and unpublished data.

3-10

Federal obligations for basic research in universities and colleges by selected supporting agencies and by selected fields, 1973 and 1976



[1] Includes only the Atomic Energy Commission prior to 1974.

[2] Data on NASA obligations for basic research are not available for 1973.

[3] Includes atmospheric sciences, geological sciences, and oceanography.

[4] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1976.

REFERENCE: Appendix tables 3–7 and 3–9.

substantial. Over all fields, this agency provided 36 percent of basic research obligations to universities and colleges. For individual fields of science and engineering in 1976, their support ranged from 17 percent in life sciences to 70 percent in environmental sciences. For six of the seven fields illustrated in Figure 3-10, NSF obligations amounted to about half or more of all basic research obligations to colleges and universities. These statistics underscore the importance of the role of NSF in the support of basic research at U.S. universities and colleges.

Institutional Concentration of Basic Research

Basic research. Institutions which award advanced degrees in science and engineering conduct most of the Nation's basic research programs. In 1975, there were 289 universities granting doctorate degrees in the sciences and engineering. These institutions accounted for 98 percent of academic basic research expenditures in 1975. Approximately 87 percent of the total expenditures for academic basic research are concentrated in 100 such institutions.[16] Only slight changes have occurred in this pattern of institutional concentration during the 1964-75 period shown in Table 3-11 below. However, there were some shifts in the positions of specific institutions; only 86 institutions were among the first 100 in basic research expenditures throughout all 4 years of the 1972-75 period.[17]

Total academic R&D.[18] Among the seven scientific areas represented in Figure 3-12, some show concentration of expenditures to a greater degree than others. There were 41 universities and colleges which ranked among the first 10 in at least one of the seven major fields. Of these, only 13 ranked among the first 10 in more than one field, and only one appeared among the first 10 in more than four fields.

The greatest concentration in 1975 was in mathematics and computer sciences where 67 percent of all R&D expenditures by universities and colleges were reported by 20 institutions, 87 percent were accounted for by 50 institutions, and 97 percent by 100 institutions. The least concentration occurred in the life sciences, where the first 20 schools accounted for only 38 percent of basic research spending, the first 50, 65 percent, and the first 100, 89 percent.

Three fields (life sciences, engineering, and the physical sciences) accounted for over 70 percent of the R&D expenditures by universities and colleges in 1975.

Relative growth of basic research and of scientists and engineers

The number of full-time-equivalent (FTE) scientists and engineers at the major research-performing universities and colleges has risen faster than have separately-budgeted basic

[16] *Expenditures for Scientific and Engineering Activities at Universities and Colleges, FY 1975*, Detailed Statistical Tables, (NSF 76-316), based on pages 3 and 5; and *Expenditures for Scientific and Engineering Activities at Universities and Colleges, Fiscal Year 1975*, (NSF 77-307), p. 25.

[17] National Science Foundation, unpublished data.

[18] Data on basic research expenditures alone are not available for separate fields of science and individual institutions. An approximation is available, however, in the form of total R&D expenditures by these institutions in scientific fields, nearly three-fourths of which is reported as basic research.

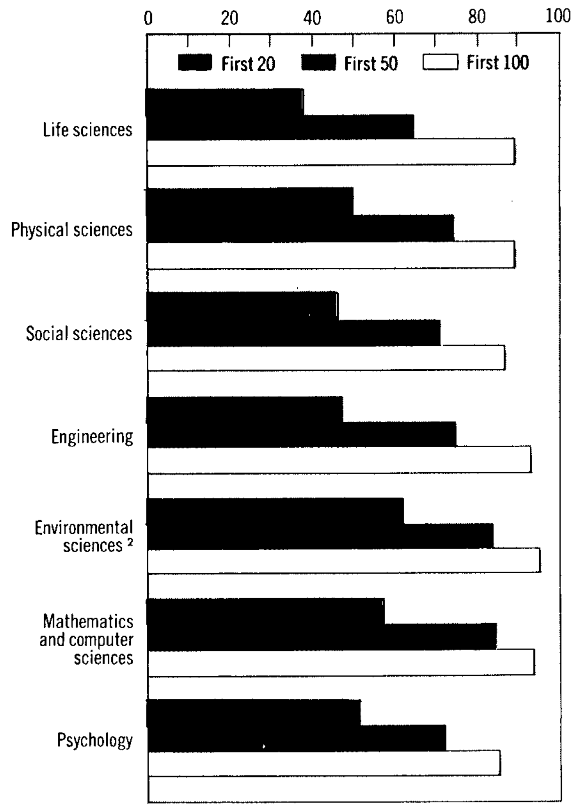
3-11 Percentage of expenditures for basic research by groups of institutions ranked in order of expenditures, 1964, and 1972-75

Year	First 10	First 20	First 40	First 60	First 80	First 100
1964	25	41	60	72	NA	NA
1972	25	40	59	72	81	87
1973	25	40	59	73	81	87
1974	24	39	59	72	81	86
1975	25	39	60	73	81	87

SOURCE: National Science Foundation, unpublished data.

3-12

Concentration of R&D expenditures at the 100 universities and colleges with the greatest expenditures in selected fields, 1975



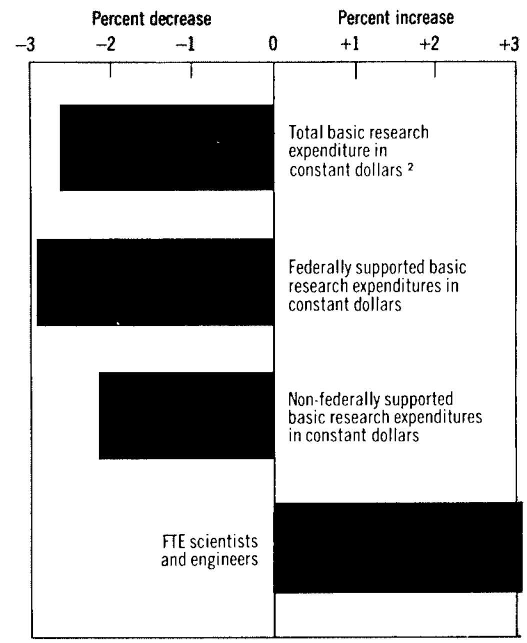
[1] Based on the ranking of total R&D expenditures in each field separately.

[2] Includes atmospheric sciences, geological sciences, and oceanography.

REFERENCE: Appendix Table 3-11.

3-13

Changes in FTE scientists and engineers and in basic research expenditures at 100 selected colleges and universities,[1] by source of funding, 1973 to 1975



[1] Those in the first 100 based on their level of basic research expenditures.

[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

REFERENCE: Appendix Table 3-12.

research expenditures (Figure 3-13). Data from a matched group of the first 100 institutions ranked each year on basic research expenditures show that while expenditures fell 2.6 percent from 1973 to 1975, the number of FTE scientists rose 3.1 percent. These institutions accounted for 86-87 percent of all basic research expenditures reported by higher education institutions in these three years.

Basic research funding from non-Federal sources dropped only 2.1 percent in real dollars, while federally supported expenditures fell 2.9 percent from 1973 to 1975. The impact of this latter change is great because only 70 percent of the total basic research expenditures in these institutions was received from the Federal Government.

BASIC RESEARCH EXPENDITURES IN FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTERS ADMINISTERED BY UNIVERSITIES

Federally Funded Research and Development Centers (FFRDC's) are organizations financed exclusively or primarily by the Federal Government to perform R&D in relatively specific areas, or in some instances to provide facilities at universities for research and associated training purposes. The Centers usually have a direct and long-term relationship with their funding agency, making it possible for them to maintain

instrumentation, facilities, and operational support beyond the capabilities of single educational or research institutions. Non-Federal organizations—academic, industrial, or nonprofit—administer the FFRDC's.

Of the Nation's total basic research expenditures in 1975, FFRDC's administered by universities and colleges accounted for 7 percent of the total.[19] These university-affiliated FFRDC's received 85 percent of the Federal basic research obligations for all three categories of FFRDC's.[20] These Centers and their sponsoring agencies are:[21]

Department of Defense

Applied Physics Laboratory
Applied Research Laboratory
Center for Naval Analyses
Lincoln Laboratory

Energy Research and Development Administration

Ames Laboratory (Iowa State University)
Argonne National Laboratory
Brookhaven National Laboratory
Fermi National Accelerator Laboratory (Fermilab)
E. O. Lawrence Berkeley Laboratory
E. O. Lawrence Livermore Laboratory
Los Alamos Scientific Laboratory
Oak Ridge Associated Universities
Plasma Physics Laboratory
Stanford Linear Accelerator Center

National Aeronautics and Space Administration

Jet Propulsion Laboratory
Space Radiation Effects Laboratory

National Science Foundation

Cerro Tololo Inter-American Observatory
Kitt Peak National Observatory
National Astronomy and Ionosphere Center
National Center for Atmospheric Research
National Radio Astronomy Observatory

[19] Calculated from Appendix Table 3-2.
[20] *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977*, Volume XXV, Detailed Statistical Tables, National Science Foundation (NSF 76-315), p. 43.
[21] See Appendix Table 3-14 for a list of the FFRDC's administered by industrial firms and other nonprofit institutions.

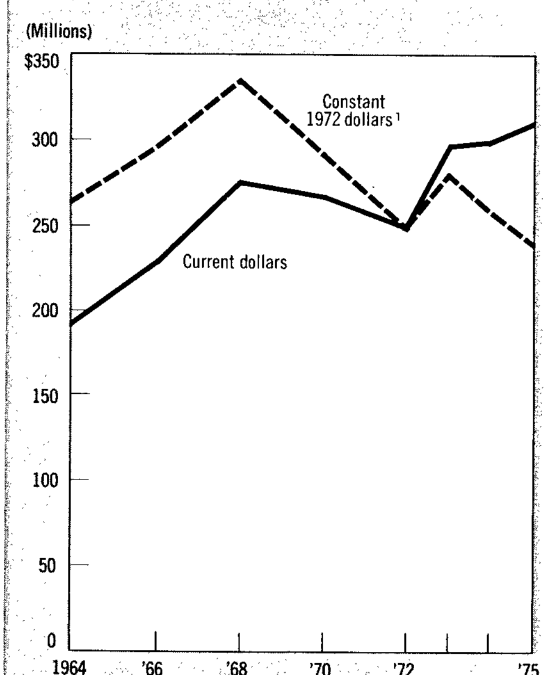
Current dollar expenditures for basic research by university-managed FFRDC's reached their highest point in 1975 (Figure 3-14). However, in constant dollars basic research expenditures by these institutions were almost 28 percent below the peak year reached in 1968. Although data are not available on expenditures for specific scientific fields, a review of the above list of Centers and the Federal agencies involved shows that the basic research they conduct is primarily in the physical sciences and engineering.

The proportion of all R&D expenditures in these academic FFRDC's reported as basic research was 31 percent in 1975, down slightly from 35 percent in the previous year (Appendix Table 3-13).

Some of the FFRDC's are permitted to receive support from sources other than the Federal

3-14

Basic research expenditures at Federally Funded Research and Development Centers administered by universities, 1964-75



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1975.

REFERENCE: Appendix Tables 3-13 and 3-14.

Government. However, such funds have amounted to less than 1 percent of their total funding in 1975 and previous years.

BASIC RESEARCH IN INTRAMURAL FEDERAL LABORATORIES

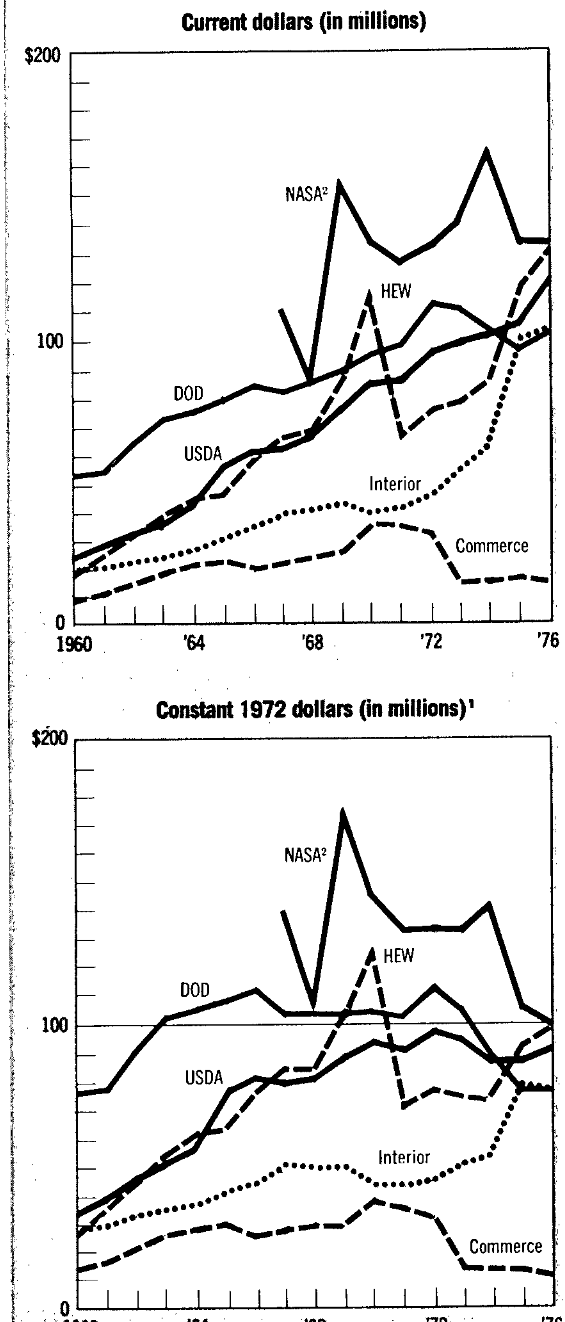
Several agencies of the Federal Government operate their own R&D laboratories as a part of their effort to meet the research needs associated with their agency mission and program objectives. Examples of such laboratories are the Goddard Space Flight Center of NASA, the intramural laboratories of the National Cancer Institute, and certain research laboratories of the USDA.

Such intramural laboratories were responsible for 15 percent of the total basic research expenditures in 1976 and 22 percent of all federally supported basic research for that year. Six agencies accounted for approximately 89 percent of the Federal funding for intramural activities (Appendix Table 3-15).

In 1976, current dollar funding for basic research in Federal intramural laboratories reached $692 million, for a rise of more than 7 percent above the 1975 level (Figure 3-15). Constant dollar totals also gained over 1975, rising by nearly 2 percent. However, in those agencies for which data are available for each year since 1960, constant dollar obligations for 1976 were below a previous peak year. The greatest decline from a peak year appeared for the Department of Commerce where the 1976 level stood 69 percent below that for 1970. Most of this change occurred between 1972 and 1973, and was primarily due to a reappraisal on the part of NOAA of the concepts used to determine percentages of their work which were considered basic and applied research; their basic research obligations have remained stable since 1973. In DOD, constant dollar obligations for intramural basic research in 1976 were 12 percent below the 1974 level, and 31 percent down from the peak reached in 1972. Obligations by HEW have grown in both 1975 and 1976. In the latter year, they rose by 32 percent above constant dollar obligations for 1974. However, they remained approximately 21 percent under their 1970 peak. For the Department of the Interior, real dollar obligations in 1975 and 1976 were nearly the same. They stood approximately 44 percent above the level reached in 1974.

3-15

Federal obligations for intramural basic research by selected agencies, 1960-76



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
[2] Data for NASA are not available for most years prior to 1967.
NOTE: Estimates are shown for 1976.
REFERENCE: Appendix Table 3-15.

BASIC RESEARCH IN INDUSTRY[22]

Industrial firms often undertake their own programs of basic research in order to provide a technical base for product improvement, prepare for expansion or new business, or provide a defense against technological obsolescence. Such programs do not have specified commercial objectives, although they are usually within the general area of a company's interest.

In 1976, 16 percent of the Nation's total basic research expenditures were accounted for by industrial performers. Approximately 3 percent of the Nation's industrial R&D spending was for basic research.[23] In current dollars, industrial basic research expenditures reached a new high in 1976, while constant dollar expenditures were comparable to those of 1972 (Figure 3-16).

Federal support to industry for basic research, measured in real dollars, was at the 1972 level in 1976 and had been near that level since 1971. Industry's own support of its basic research has been almost level in constant dollars since 1972, but in 1976 was 23 percent below the peak year of 1966.

Approximately 22 percent of basic research expenditures in industry were from Federal sources in each year of the period 1971-76. The Federal share had been as high as 32 percent in 1967.

Some industrial firms also administer Federally Funded Research and Development Centers (see Appendix table 3-14). In 1974, 31 percent of Federal funds for basic research in industry, and 7 percent of all spending in industry for basic research were accounted for by such Centers.[24]

Four industries accounted for 77 percent of industrial basic research expenditures in 1974 (Figure 3-17). These industries, and the percentage accounted for by each of them, were: chemicals and allied products (39 percent), electrical equipment and communication (27 percent), aircraft and missiles (8 percent), and machinery (4 percent).

The bulk of industrial basic research is conducted in the areas of engineering and physical sciences. In 1974, work in these fields accounted for 71 percent of all industrial basic research (Appendix Table 3-18).

Constant dollar expenditures for industrial basic research in engineering reached a new low in 1974, falling some 16 percent below the 1973 level, and 13 percent below the previous low mark reached in 1971 (Figure 3-18). In physics and astronomy, industrial basic research expenditures in 1974 were at nearly the same level as those for 1973. However, they were 59 percent below the 1967 peak (when data first became available). Chemistry saw an upturn of 9 percent in real dollars from 1973 to 1974. Expenditures in the life sciences (biological and clinical medical sciences combined), also measured in constant dollars, were roughly the same in 1973 and 1974, standing slightly below the peak year reached in 1971.

BASIC RESEARCH IN NONPROFIT INSTITUTIONS

Independent nonprofit institutions are organizations other than educational institutions chartered to serve the public interest, and include research institutes, private independent hospitals, private foundations, science exhibitors, professional societies, trade associations, and the FFRDC's administered by such nonprofit institutions. The largest single category is the research institute. The others generally perform other services in addition to research, such as patient care or charitable activities.

Approximately 6 percent of the Nation's basic research in 1976 was performed by these nonprofit institutions. Their share of basic research has remained at approximately this level since the late 1960's.

In current dollars, estimated expenditures in nonprofit institutions for basic research were at their highest in 1976. However, real dollar expenditures have declined at an average annual rate of approximately 3 percent in the period 1972 to 1976, falling, in the latter year, to the lowest level since 1961 (Figure 3-19).

Funds for basic research in these institutions are provided largely by Federal sources. The Federal share was as high as 58 percent in 1966, but fell to 45 percent in 1976. The only other

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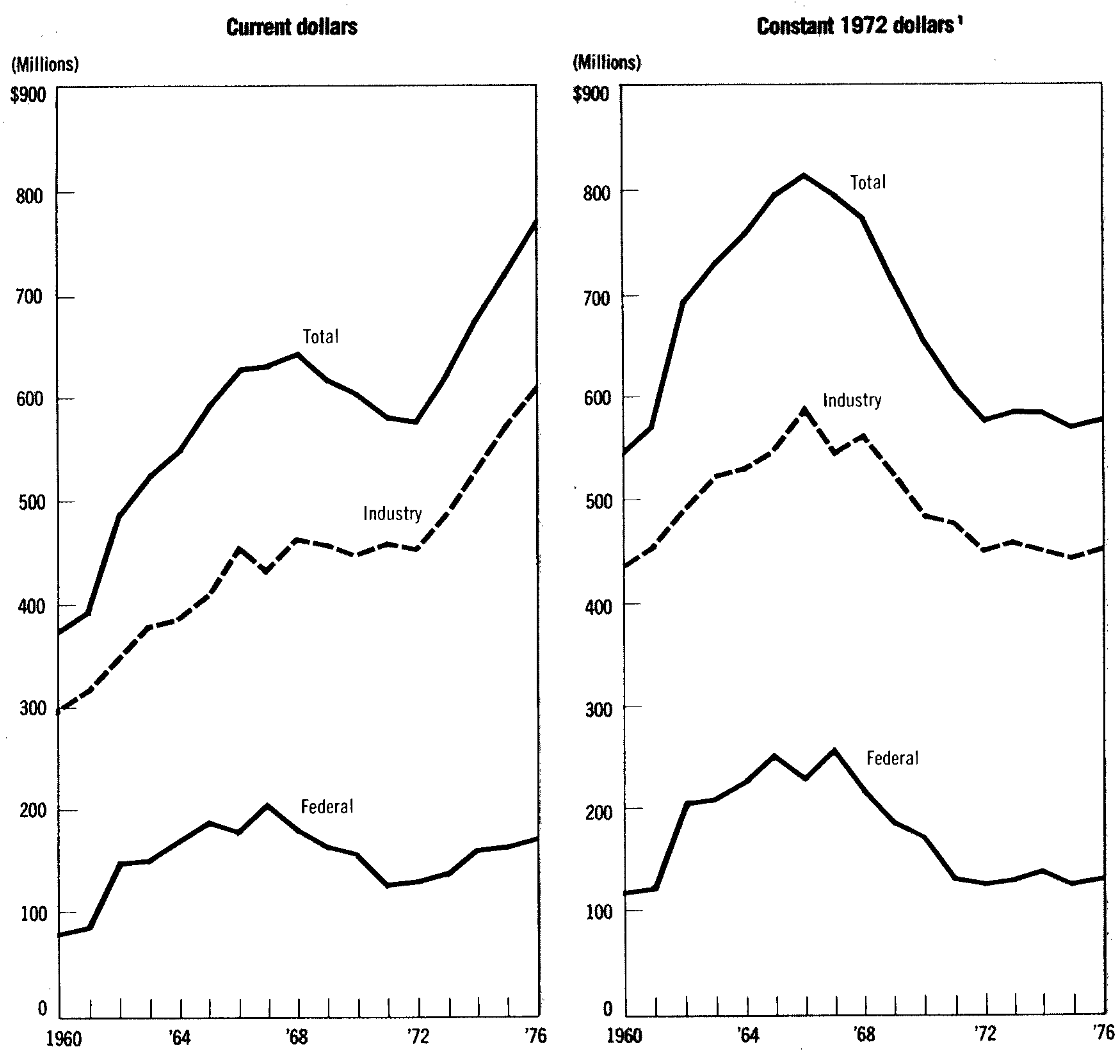
[22] A more comprehensive discussion of R&D in industry can be found in another chapter entitled, "Industrial R&D and Innovation".

[23] *National Patterns of R&D Resources, 1953-76,* National Science Foundation (NSF 76-310), calculated from pp. 21, 23.

[24] *Research and Development in Industry, 1974,* National Science Foundation (NSF 76-322), calculated from pp. 15, 62, 63.

3-16

Basic research expenditures in industry by source, 1960-76



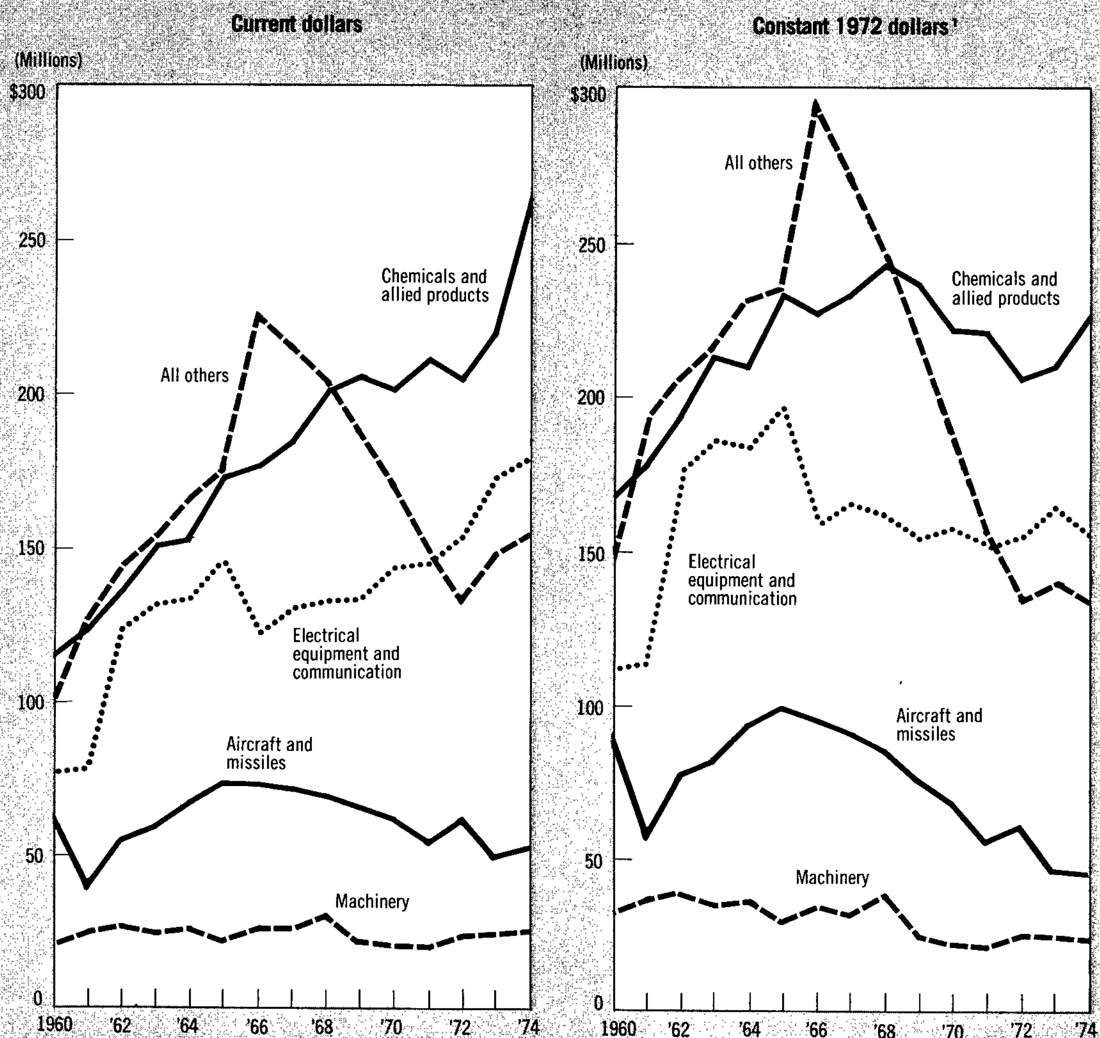
[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1975 and 1976.

REFERENCE: Appendix Table 3-16.

3-17

Expenditures for basic research in industry by major R&D-performing industries, 1960-74

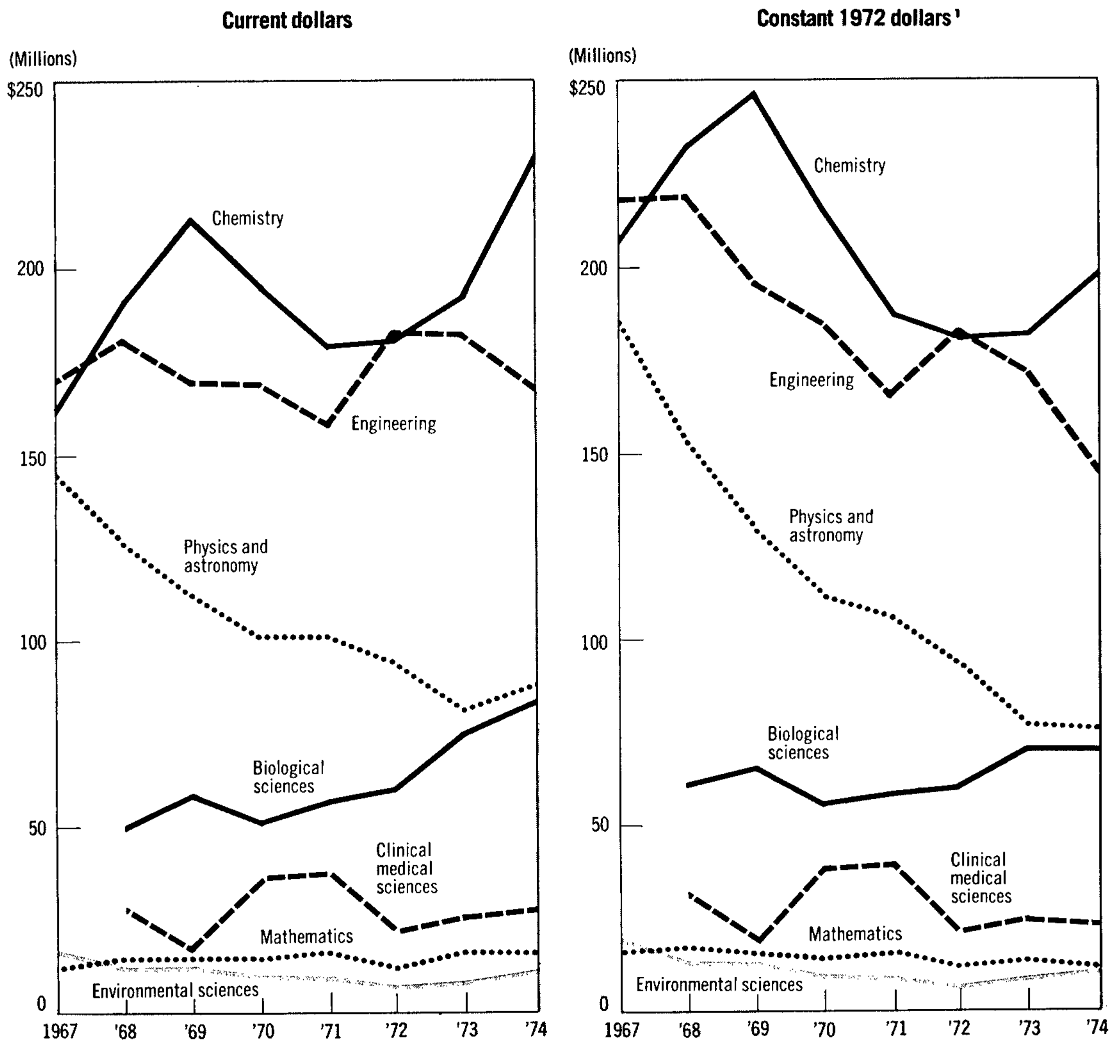


[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

REFERENCE: Appendix Table 3-17.

3-18

Expenditures for basic research in industry by selected fields, 1967-74

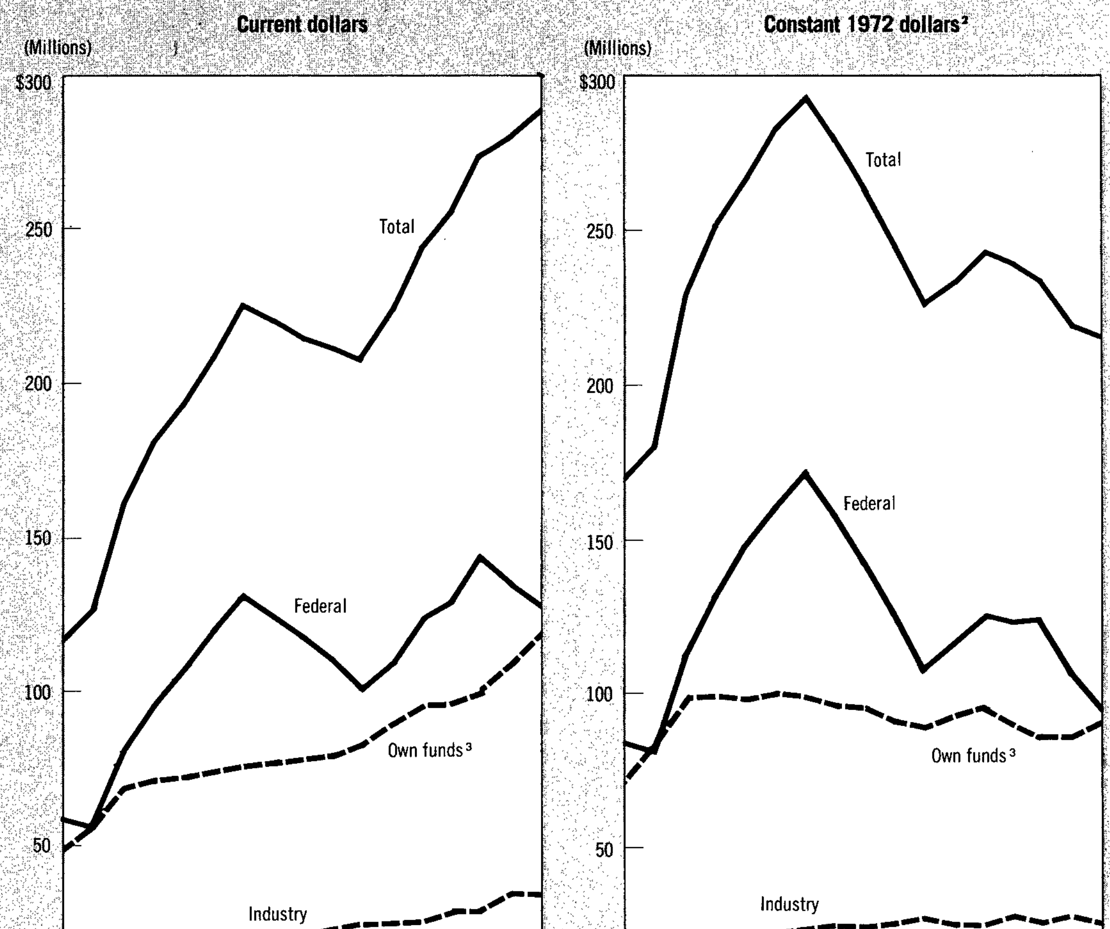


[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

REFERENCE: Appendix Tables 3-18 and 3-19.

3-19

Basic research expenditures in nonprofit institutions[1] by source, 1960-76



[1] Includes State-administered hospitals.
[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
[3] Includes State and local government funds.
NOTE: Estimates are shown for 1975 and 1976.
REFERENCE: Appendix Table 3-20.

time it reached this level was in 1961. Industry provided 12 percent of expenditures in 1976, while other sources provided 43 percent.

Basic research as a proportion of total research and development expenditures by these institutions declined from 38 percent to 23 percent over the period 1960-76.

RESEARCH OUTPUTS AND APPLICATIONS

Thus far, this chapter has attempted to present a partial picture of the financial aspects of the state of basic research activities in the Nation by examining various elements which are utilized in the basic research enterprise, and studying how they are consumed by researchers and their sponsors. While such analyses are useful, a more complete picture might be possible by studying the output of the basic research enterprise as well. The following studies are among the initial efforts to assess the basic research effort in terms of its outputs and applications.

Scientific research literature

Information on the number of research reports published by various sectors of the R&D community in several fields of science was obtained from a study conducted by the National Federation of Abstracting and Indexing Services.[25] The study involved the selection of a set of U.S. scientific and engineering journals which were intended to be representative of the total literature in each field. This was accomplished largely through the guidance of the Federation's member services and by advice from experts active in the fields. On a sampling basis, individual reports in the journals were examined to determine the first author's institutional affiliation: academic, government, industry, or other nonprofit organization. The sample of reports was restricted to those whose first authors were affiliated with U.S. institutions; from 73 to 89 percent of articles by U.S. authors are published in U.S. journals, depending on the field.[26]

The data obtained from the study were used to develop preliminary measures of the relative growth of several fields of science and engineering in terms of their publication output, and the roles of the different sectors in the overall research effort of each field.

Growth in research output. Between 1960 and 1975 the number of articles in scientific research publications has grown substantially in the 13 fields of science represented in Figure 3-20. Some fields have grown much more rapidly than others. The largest relative growth since 1960, among those fields for which data are available, occurred in the atmospheric sciences, and the smallest in economics.[27]

The fields listed in Groups I to IV of Figure 3-20 are presented in descending order with respect to the magnitude of their relative growth in publications during the 1960-75 period. The fields included in Group I grew by more than 200 percent during the period, those in Group II by more than 100 but less than 200 percent, those in Group III by more than 75 but less than 100 percent, and those in Group IV by less than 75 percent.

For all fields combined, the number of articles relative to 1960 increased by 148 percent in 1974 and an estimated 154 percent in 1975 (Appendix Table 3-21). In six fields of science, growth of articles relative to 1960 was higher in 1974 than in 1973, while in seven fields growth relative to 1960 was lower in 1974 than in 1973.[28] Available data for 1975 showed steady growth in only 3 of 11 fields since 1973; five fields not changing substantially from the 1973 level; and three dropping below the 1973 level. The largest growth between 1973 and 1975 occurred in the atmospheric sciences which advanced 139 percentage points above the relative growth recorded in 1973, for an almost four-fold expansion of the publication level of 1960.

[25] *Science Literature Indicators Study, 1975*, (Philadelphia: National Federation of Abstracting and Indexing Services, 1976, a study commissioned specifically for this report).

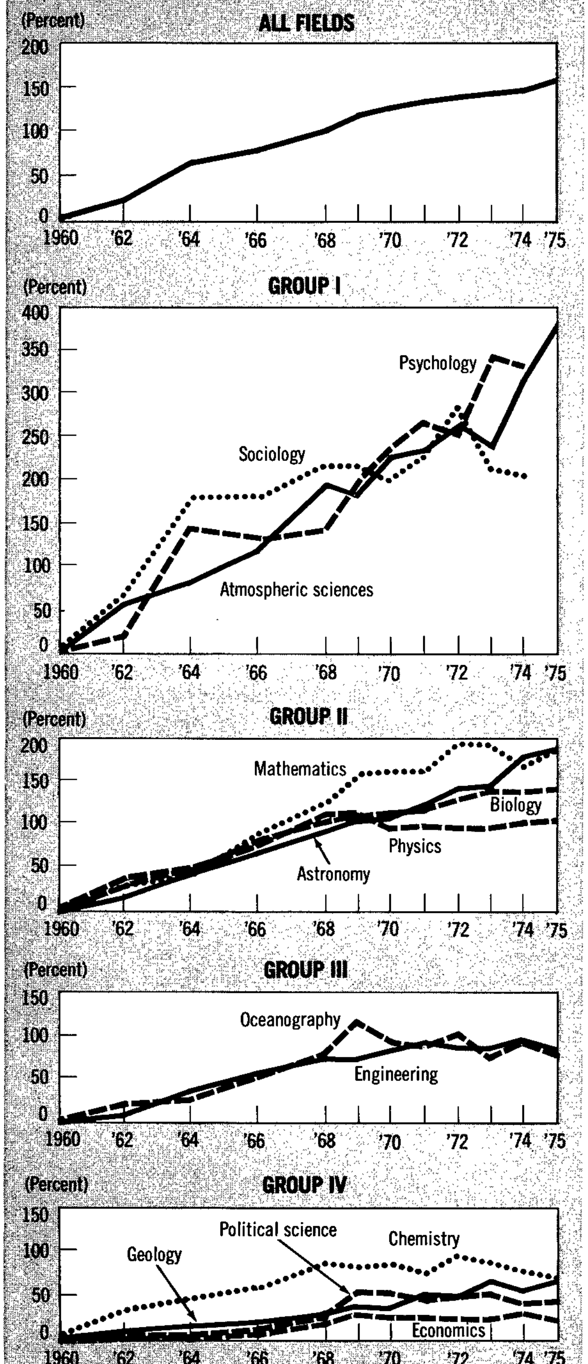
[26] Computer Horizons, Inc., unpublished data.

[27] Data for the fields of psychology and sociology are available only through 1974. Totals for these fields were not individually estimated for 1975, although total publications for 1975 were estimated from data for previous years. In Figures 3-20 and 3-21, and in the following discussion of them, overall data for 1975 were used whenever possible. However, it should be noted that discussions of fields or sectors that describe largest or smallest growth are based on only 11 of 13 fields for 1975.

[28] For information on the U.S. scientific literature in an international context, see the chapter of this report entitled, "International Indicators of Science and Technology".

3-20
Relative growth in scientific research articles by selected fields of science, 1960-75

(Percent growth after 1960)



NOTE: Estimates are shown for 1975 in the "All Fields" figure.
REFERENCE: Appendix Table 3-21.

Research output by sectors. The research articles produced by each sector—university, government, industry, and other nonprofit organizations—are shown in Figure 3-21 for five selected fields (data for each of the 13 fields are presented in Appendix Table 3-22).

In the 11 fields for which 1975 data are available, the largest producers of published research reports were universities with an average 73 percent of the articles. Government and industry each accounted for 11 percent in that year, while nonprofit institutions had 4 percent. The role of universities in the production of such reports has grown since 1960 when they accounted for 61 percent, while the share produced by governmental and industrial sectors have both declined from their respective 16 and 15 percent shares of 1960.

In the two remaining fields (psychology and sociology) the academic sector has also accounted for most of the research articles. Between 1970 and 1974 this sector produced an average of 73 percent of such reports in psychology and an average of 87 percent in sociology. In psychology, governmental and industrial sectors averaged 6 and 3 percent respectively of publications in the 1970-74 period, while in sociology these sectors produced an average of 3 and 1 percent respectively in the same period.

In the academic sector, its share of articles increased the most between 1960 and 1975 in the fields of geology, chemistry, physics, and mathematics (including computer science).

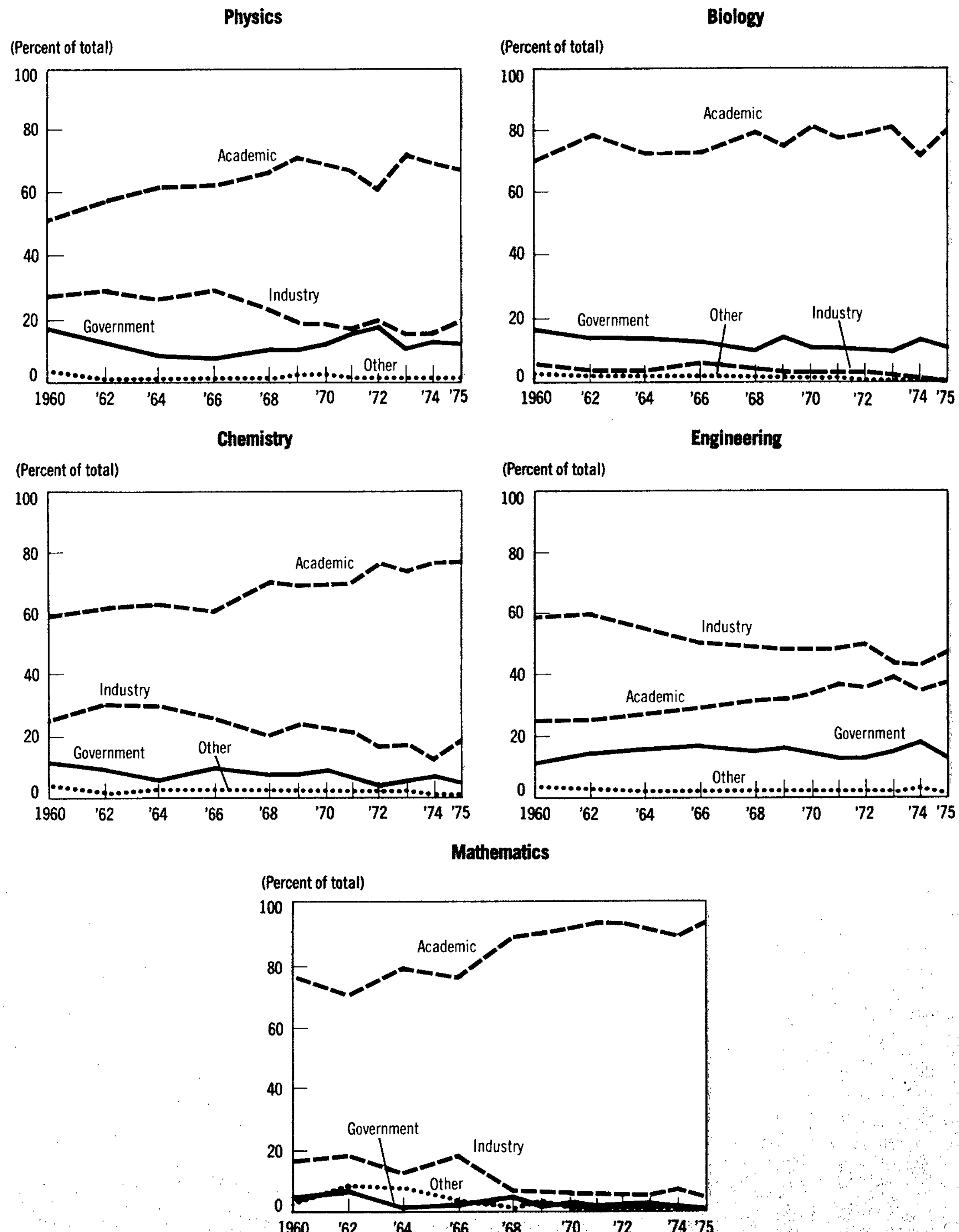
The 11 percent average share of published research reports accounted for by the Federal Government in 1975 was down from the 15 percent share held in 1960. Its share of articles dropped in 10 of 11 fields for which data are available. The only field reflecting an increased share by this sector was engineering, while the greatest decreases were shown for astronomy, atmospheric science, oceanography, and chemistry.

Private industry also held an average share of 11 percent in 1975, compared with a 13 percent share in 1960. Its share of articles in 1975 increased in three fields (political science, atmospheric science, and oceanography) but decreased in eight fields. The largest decreases were in mathematics, engineering, and physics.

Nonprofit institutions accounted for an average share of 4 percent in 1975, roughly equal to the 1960 share.

3-21

Publication output for selected fields of science, percent of yearly totals by sectors, 1960-75



REFERENCE: Appendix Table 3-22.

Chapter 4

Industrial R&D and Innovation

Industrial R&D and Innovation

INDICATOR HIGHLIGHTS

- It is estimated that the total expenditure for R&D in industry was $26.5 billion in 1976, up 9 percent over the 1975 estimate and 2½ times the 1960 level. The 1960-76 increase resulted primarily from increases in industry's own R&D funds.

- When measured in constant dollars, total industry R&D spending is expected to show a 4-percent increase between 1975 and 1976. This marks the first increase in constant-dollar industrial R&D expenditures since 1973.

- In January 1975 there were an estimated 357,500 R&D scientists and engineers employed by industry. This number has remained level since 1973 but is down nearly 8 percent from the 1969 high of 387,100. The entire decrease since 1969 can be attributed to a drop in the number of federally supported R&D scientists and engineers.

- Six industries accounted for over 85 percent of all industrial R&D spending in 1974. They were electrical equipment and communication, aircraft and missiles, machinery, motor vehicles and other transportation equipment, chemicals and allied products, and professional and scientific instruments.

- According to estimates, industry spent $1.6 billion on energy R&D projects in 1976 with 37 percent of that amount going for fossil fuel R&D, primarily in petroleum. Another 49 percent was directed to nuclear energy. An estimated $663 million was spent on pollution abatement R&D projects in 1976, with 74 percent of that directed toward air pollution programs.

- More than two-thirds of total industrial applied research and development expenditures were in six product areas in 1974: communication equipment and electronic components, machinery, aircraft and parts, guided missiles and spacecraft, motor vehicles and other transportation equipment, and chemicals.

- The group of industries with the greatest R&D intensity (i.e., the greatest company and total R&D expenditures as a percent of net sales and the greatest number of R&D scientists and engineers per 1,000 employees) has seen an almost steady drop in the second and third of these factors since their highest level was reached in 1964.

- The number of U.S. patents granted per year to U.S. inventors reached a peak in 1971 and has declined steadily since then. The number granted to foreign inventors has increased almost every year since 1963. The number assigned to U.S. corporations also reached a peak in 1971, while the number assigned to U.S. individuals peaked in 1974.

- The percent of patents due to foreign inventors increased in nearly every product field from 1965 to 1975. Foreign patenting is especially high in the motorcycle and bicycle, drug, railroad equipment, organic chemicals, aircraft, and nonferrous metals industries.

- In 1975, U.S. corporations owned the highest percentage of U.S. patented inventions due to U.S. inventors in the chemical, petroleum, and drug industries. U.S. Government ownership was highest in ordnance and missiles. U.S. individuals had their greatest percentage of patents in shipbuilding, farm and garden equipment, construction machinery, and refrigeration machinery.

- On the basis of a sample of major innovations introduced to the market between 1953 and 1973, small firms (up to 1,000 employees) were found to produce about 4 times as many innovations per R&D dollar as medium-sized firms (1,000 to 10,000 employees) and about 24 times as many as large firms (over 10,000 employees). The total number of innovations produced by small firms was greater than for large firms,

and both produced more than medium-sized firms.

- The most R&D-intensive manufacturing industries produced the majority of the sample of major innovations during the 1953-73 period; these industries accounted for 59 percent of the innovations, followed by intermediate-level industries with 21 percent and the least R&D-intensive industries with 9 percent. R&D-performing nonmanufacturing industries accounted for 11 percent. The more R&D-intensive groups had fewer innovations per R&D dollar.

- The largest percentage of the sample of major innovations introduced in 1953-73 were rated as technological improvements (38 percent), followed by major technological shifts (28 percent), and radical breakthroughs (26 percent). The remainder were rated at most as imitations. The fraction called radical breakthroughs declined from 36 percent in 1953-59 to 16 percent in 1967-73, while those rated as major technological shifts increased correspondingly. This change was primarily due to a drop in radical breakthroughs reported by the most R&D-intensive industries.

- In proportion to net sales, the greatest numbers of major innovations in the sample were produced by the professional and scientific instruments industry and the stone, clay, and glass products industry. In terms of their R&D expenditures the industries producing the most innovations were stone, clay, and glass products; wood products; textiles; and rubber.

- The most frequently cited source of the technology underlying major innovations was applied research, most of which was performed within the innovating company. Second in frequency was basic research, most of which again was internal, followed by the transfer of technology from an existing product of the same firm. Centralized corporate R&D activity was often cited, but did not account for all of the underlying internal research.

- Public funds assisted in the development of 24 percent of the sample innovations produced by the most R&D-intensive group of industries and 36 percent of those from the reporting nonmanufacturing industries. Other industries had fewer innovations assisted by public support.

- Sixty percent of the inventions underlying major innovations occurred in the profit center that produced the innovation and 25 percent elsewhere in the same enterprise. Independent inventors and universities contributed less frequently.

Research and development provides a basis and much of the impetus for the technological innovation that occurs in industry. The results of innovation are new and improved products, processes, and services. These are the elements of technological progress, leading to significant improvements in the Nation's productivity, economic health, and standard of living.

Industrial R&D activity comprises basic research, applied research, and development. Basic research consists of original investigations directed toward the advancement of scientific knowledge, which do not have specific commercial objectives, but may be in fields of interest to the performing company. Applied research consists of those scientific investigations that are directed toward specific commercial products or processes. Development is the engineering work required to move a product to the point where it is ready for manufacturing. The character and extent of industrial R&D activity vary considerably, from industry to industry and from company to company.

Although the innovation process is complex, expensive, and risky, failure of a firm or an industry to be innovative may mean the economic failure of that firm or industry as well, with consequences for the general economy. R&D must compete for funds and manpower with other possible areas of investment, but for many firms R&D investment is found to be both necessary and competitive in its returns with other possible allocations of funds.

In this chapter indicators of the state of industrial R&D and innovation are presented in

terms of the levels of input to and output from the innovation process. Input indicators describe the dollar expenditures and scientific and engineering manpower levels devoted to industrial R&D. Indicators of the output from this investment take the form of the numbers of patents and innovations produced by R&D-performing industries, as these depend on the R&D intensity of different industries and other variables. The chapter concludes with a summary of major findings from studies of the effect of R&D and innovation on the economy and society as a whole.

RESOURCES FOR INDUSTRIAL R&D

The money and personnel allocated to industrial R&D are among the essential inputs to that effort, and therefore can serve as indicators of its magnitude. One such indicator which is presented in the following sections is the total expenditure for industrial R&D from year to year, which is further analyzed according to the source of the funds and the specific industry within which they are spent. The numbers of personnel working in industrial R&D are presented in a similar way. Special attention is given to industrial R&D efforts in energy and pollution abatement. Next there follow indicators of the distribution of industrial R&D resources among basic research, applied research, and development. The allocation of applied research and development funds among product fields is then discussed. Data are presented also on the distribution of R&D expenditures among companies of different sizes, and finally industries are classified according to the intensity of their R&D efforts.

In interpreting these indicators, it must be kept in mind that R&D is not the only input to the innovation process in industry. As later sections will point out, there are subsequent steps in the process which may in fact require much greater expenditures than those that go into R&D. Such steps include tooling, manufacturing start-up, and marketing start-up. R&D itself can be taken to include research and advanced development (e.g., in a pilot plant), including basic invention and engineering and designing of the product. In 1967 one panel published an estimate, widely quoted since, that such R&D amounts to 15 to 30 percent of the typical costs in successful product innovation.[1] A 1971 study of 38 product innovations in three industries found R&D to be 46 percent of the total innovative cost, on the average.[2] For 83 product and process innovations occurring in Canada, the expenditure on R&D was 59 percent of the total cost of innovation.[3]

These figures are affected by the different ways in which the various studies defined the stages of the innovation process. They are also affected, of course, by any differences that may exist between the industries and countries involved in those studies.[4] But they suffice to show that the costs of R&D are a significant portion, but by no means all, of the total cost of technological innovation.

Expenditures for industrial R&D

U.S. industry performs nearly 70 percent of the Nation's total R&D, on a dollar basis.[5] Since 1960 there has been a steady increase in funding for industrial R&D with the exception of a drop from 1969 to 1970, as shown in Figure 4-1. When growth in R&D funding resumed in 1971, it continued through 1976 according to estimates; the compound annual rate of increase from 1970 to 1976 is about 6.5 percent, the same as in the 1960-69 period. Most of the increase, however, was absorbed by higher prices for R&D inputs; the yearly constant dollar expenditures since 1970 oscillate and show no definite trend.

Current estimates place expenditures for industrial R&D at $26.5 billion in 1976. This is 9 percent above the estimate for 1975, and 2½ times the 1960 level. When measured in constant dollars, total industry R&D spending is expected to show a 4 percent increase from 1975 to 1976.

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[1] *Technological Innovation: Its Environment and Management*, Department of Commerce, 1967.

[2] E. Mansfield, et al., *Research and Development in the Modern Corporation*, (New York: MacMillan, 1971).

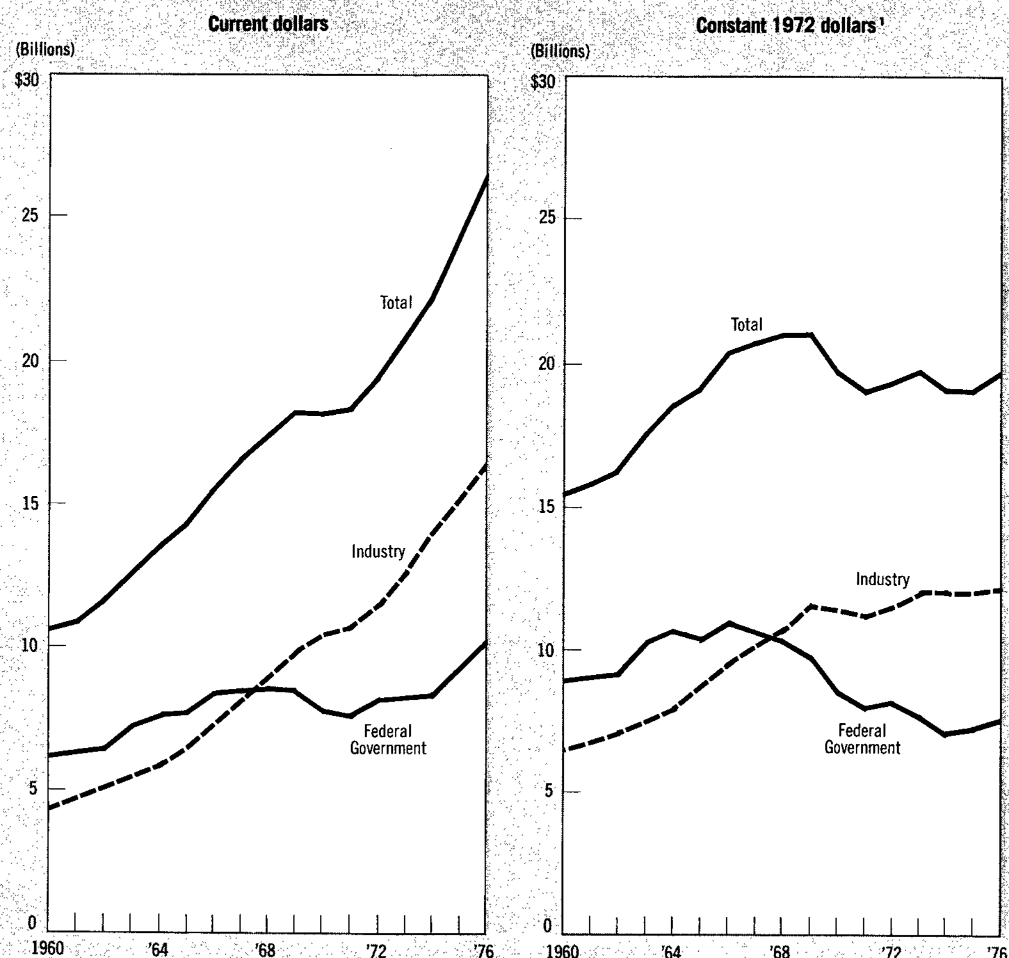
[3] *Selected Statistics on Technological Innovation in Industry*, STC Cat. No. 13-555, Statistics Canada, 1975.

[4] On all three studies, see H. Stead, "The Costs of Technological Innovation", *Research Policy*, Vol. 5 (1976), pp. 2-9.

[5] *National Patterns of R&D Resources, 1953-76*, National Science Foundation (NSF 76-310), p. 4. Industrial R&D expenditures presented in this report include all costs incurred in support of R&D (i.e., salaries, laboratory equipment, overhead, etc.), but do not include associated capital expenditures. See *Research and Development in Industry, 1974*, National Science Foundation (NSF 76-322), p. 17, for further information on the scope of these costs.

4-1

Expenditures for industrial R&D by source of funds, 1960-76



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1975 and 1976.

REFERENCE: Appendix Table 4-1.

This is the first time since 1973 that industry's real R&D expenditures are expected to increase.

Figure 4-1 also shows the two sources of the R&D funds spent in industry for each year: Federal Government and industry's own funds, which include State government funding and all other sources. Largely because of the decline in R&D funds from the National Aeronautics and Space Administration (NASA), which began about 1966, Federal support of industrial R&D leveled off and dropped below industry's own funds in 1968. Federal R&D funds accounted for an estimated 38 percent of total industry R&D expenditures in 1976 compared with 58 percent in 1960.

Among individual industries, federally financed research and development accounts for different proportions of their total R&D activity. Virtually every major industry performs some research and development for the Federal Government. However, as shown in Table 4-2 for the latest year for which data are available, two industries—aircraft and missiles, and electrical equipment and communication—were by far the most heavily engaged in Federal R&D work.

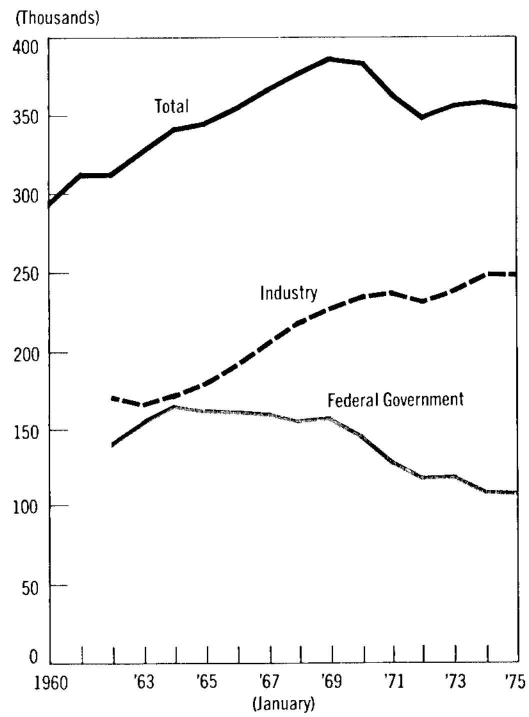
4-2. Federal funding as a percentage of total industrial R&D expenditures, by manufacturing industry,[1] 1974

Industry	Percent
Aircraft and missiles	78
Electrical equipment and communication	47
Professional and scientific instruments	18
Machinery	14
Motor vehicles and other transportation equipment	13
Rubber products	10
Chemicals and allied products	9
Fabricated metal products	5
Petroleum refining and extraction	3
Primary metals	3
Textiles and apparel	1
Stone, clay, and glass products	1

[1] The comparable figure for all reporting nonmanufacturing industries combined is 60 percent.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), pp. 26 and 29.

4-3
Scientists and engineers[1] engaged in industrial R&D by source of funds, 1960-75



[1] Full time equivalent basis
NOTE: Preliminary data are shown for 1975
REFERENCE: Appendix Table 4-2.

Industrial R&D personnel

Between 1973 and 1975 the number of industrial R&D scientists and engineers showed little change. The 1975 level of 357,500, however, does represent a marked reduction from that reported in 1969 when total employment of industrial R&D scientists and engineers reached 387,100. From Figure 4-3, it is obvious that the decline in Federal R&D funds has been the major factor in this trend. Between 1969 and 1975, the number of industrial R&D scientists and engineers supported by Federal funds declined by almost 50,000 while those supported by industry funds increased by almost 20,000. Aircraft and missiles firms and electrical equipment and communication companies accounted for four-fifths of the drop in federally supported R&D science and engineering professionals employed by industry.[6]

These data on the number of scientists and engineers engaged in the performance of industrial research and development are provided as a second indicator of the level of R&D activity, complementing data on R&D expenditures expressed in constant dollars. As shown in Figure 4-4, the trend lines representing growth in annual total employment of R&D scientists and engineers and in constant dollar R&D expenditures compare quite closely throughout the 1960-75 period.

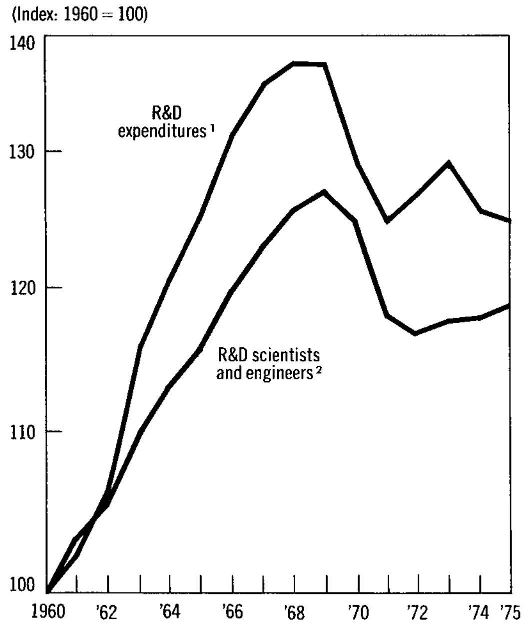
R&D expenditures by individual industries

The role of research and development in the continued growth and prosperity of any industry is determined by several factors—the types of industrial activity undertaken, the state of technology in that activity, the nature and

[6] *Research and Development in Industry, 1974,* National Science Foundation (NSF 76-322), p. 46, and *Research and Development in Industry, 1969,* National Science Foundation (NSF 71-18), p. 43.

4-4

Scientists and engineers engaged in industrial R&D, compared with constant dollar expenditures for industrial R&D, 1960-75



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
[2] Full-time-equivalent basis, averaged for each year.
NOTE: Estimates are shown for 1975.
REFERENCE: Appendix Table 4-3.

extent of competition, the availability of natural resources and, especially in recent years, performance, safety, and pollution regulations imposed by government. Furthermore, among firms within an industry, the decision to support an R&D program is a matter of management outlook and policy. It is not surprising, therefore, that the level and characteristics of R&D activity show considerable variation among industries.

Some level of R&D activity can be found in virtually all manufacturing industries and many nonmanufacturing industries. However, only certain nonmanufacturing industries report significant levels of expenditures for R&D. The combined effort of this group represents less than 4 percent of all industrial R&D spending.[7] Six manufacturing industries reported R&D expenditures over the billion dollar level in 1974, and together they accounted for 85 percent of total industrial R&D spending (Figure 4-5). The six industries are electrical equipment and communication, aircraft and missiles, machinery,[8] motor vehicles and other transportation equipment, chemicals and allied products, and professional and scientific instruments. The increases in R&D spending from 1973 to 1974 in three of these industries—chemicals (15 percent), machinery (14 percent), and instruments (11 percent)—were well ahead of the 7 percent growth rate in total industrial R&D spending.[9]

The 1960's saw a steady and substantial growth in individual industries' R&D expenditures in terms of both current and constant dollars. After that, inflation began to cut into the increases budgeted for research and development, which can be seen in Figure 4-6. Beginning in 1970, aircraft and missiles firms experienced a substantial drop in R&D activity brought on by cutbacks in the Government's space program. Growth in R&D spending by this industry has since resumed, but expenditures still are short of the peak reached in 1969. On the other hand, chemicals, machinery, and instruments reported peak-year performances in 1974 in terms of both current and constant dollars.

R&D expenditures on energy sources and pollution abatement

Two growing areas of industry's civilian R&D activity are the development of energy sources and pollution abatement. It is estimated that $1.6 billion was spent in industry for energy R&D in 1976. This is 10 percent above the 1975 figure and 57 percent above that for 1973 (see

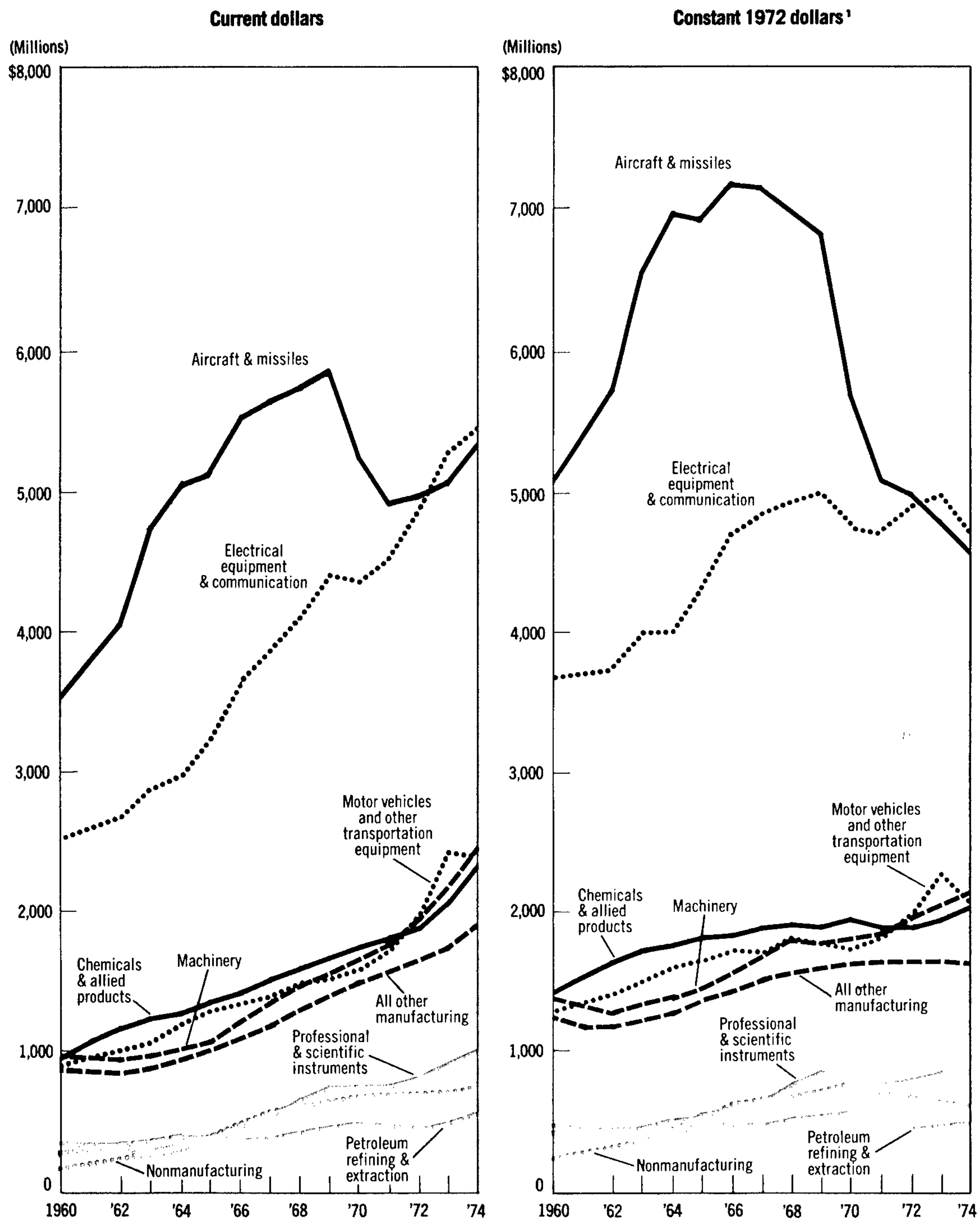
[7] *Research and Development in Industry, 1974,* National Science Foundation (NSF 76-322), p. 26. These nonmanufacturing industries are: agricultural services; forestry, hunting, and fisheries; mining; construction; nonrail transportation and other public utilities; wholesale and retail trade; finance, insurance, and real estate; and selected service industries. These are the "nonmanufacturing industries" discussed throughout this chapter.

[8] Includes office, computing, and accounting machines; metalworking machinery; engines and turbines; farm machinery; construction, mining, and materials handling machinery.

[9] R&D expenditures by all industries are presented in Appendix Table 4-4.

4-5

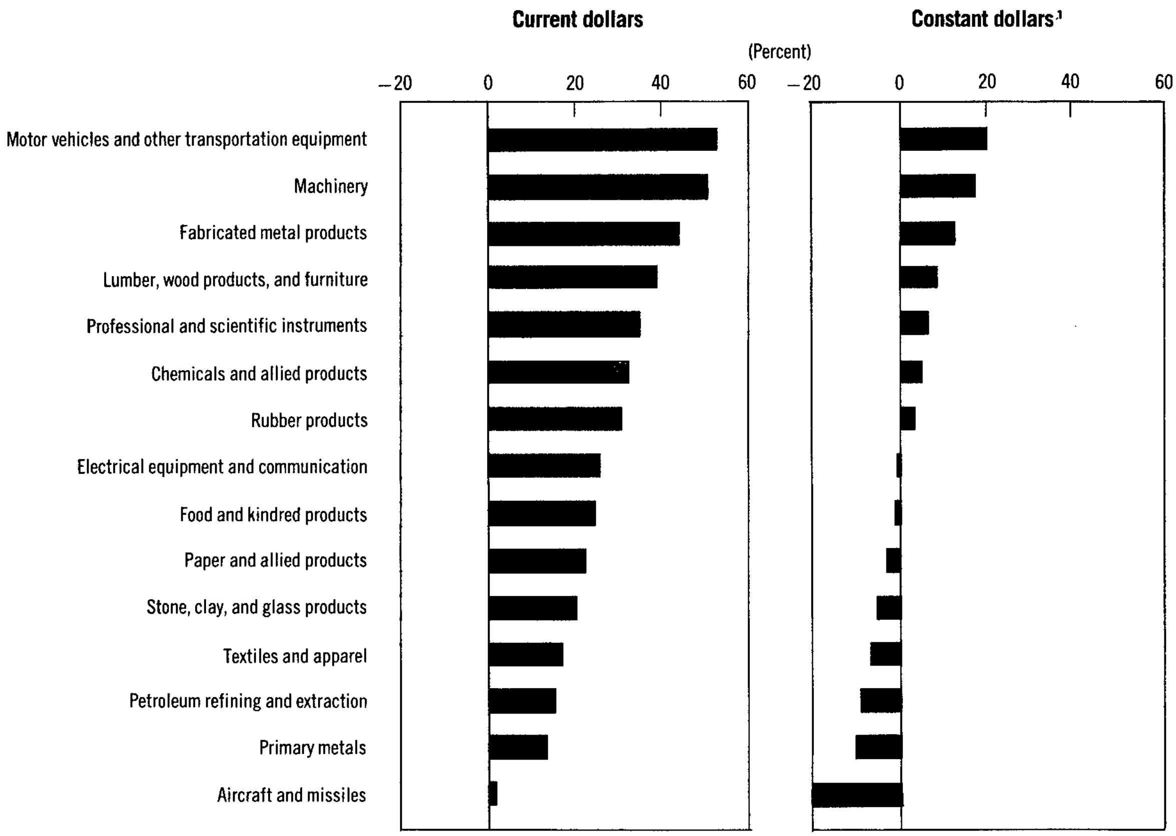
R&D expenditures by individual industries, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

REFERENCE: Appendix Table 4-4.

4-6
Industrial R&D expenditures, percent change, 1970-74



[1] GNP implicit price deflators used to convert current to constant dollars.
REFERENCE: Appendix Table 4-5.

Table 4-7). It is also 6 percent of all industrial R&D expenditure estimated for 1976, according to Appendix Table 4-1. The first four industries listed on Table 4-7 account for about 80 percent of the total expenditure for energy R&D in each year. The greatest percentage increases from 1973 to 1976 are in nonmanufacturing industries, chemicals, and aircraft, while the largest dollar increases are in the electrical equipment and petroleum industries.

Almost half of the total R&D funds spent on energy production in industry have consistently gone into nuclear processes (Table 4-8). The great bulk of this goes into fission processes. Fossil fuels are second only to nuclear fuels in funds expended, but their share dropped from 43 percent in 1973 to an estimated 37 percent in 1976. In the same interval, the greatest percent changes have occurred in the less highly funded areas of geothermal and solar energy. High percentage increases also occurred in energy conservation and utilization.

The Federal Government's share in funding for energy R&D went from 38 percent in 1973 to 43 percent in 1975. In coal R&D the federally funded share rose from 14 to 22 percent. Nuclear energy is the area which is most heavily supported by the Government. In 1975 Federal support stood at 77 percent of all funds spent for nuclear energy R&D, which was also 87 percent of all Federal support for energy R&D. On the other hand, conservation and utilization is an area in which non-Federal support is growing faster than Federal support: The companies' own

4-7. Industrial expenditures for energy R&D, by industry, 1973-76

(Dollars in millions)

Industry	1973	1974	1975	1976 (est.)
All industries	$1,004	$1,213	$1,427	$1,577
Electrical equipment and communication	318	389	461	516
Petroleum refining and extraction	313	375	412	450
Aircraft and missiles	101	129	169	176
Chemicals and allied products	58	84	116	123
Other manufacturing industries	176	187	214	233
Nonmanufacturing industries	38	49	55	79

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), p. 59, and *Science Resources Studies Highlights*, "Energy Increase of 18 Percent Paces Industrial R&D Spending in 1975", October 27, 1976 (NSF 76-324).

4-8. Industrial expenditures for energy R&D, by energy source and source of funding, 1973-76

(Dollars in millions)

Primary energy source	1973			1974			1975			1976
	Total	Federal	Company[1]	Total	Federal	Company[1]	Total	Federal	Company[1]	Total (est.)
All energy sources	$1,004	$385	$619	$1,213	$482	$731	$1,427	$620	$807	$1,577
Fossil fuel	433	10	423	507	13	494	549	31	518	591
Oil	297	2	295	325	3	322	335	5	330	353
Coal	49	7	42	65	9	56	98	22	76	118
Mining	NA	NA	NA	4	3	23	8	7	38	9
Synthetic fuel	NA	NA	NA	21			37			47
Other	NA	NA	NA	39	6	33	53	15	38	60
Shale	7	0	7	13			14			13
Gas	51			74	1	116	76	4	112	75
Other fossil fuel	29	1	79	30			26			31
Nuclear	501	366	135	601	444	157	698	537	161	765
Fission	476	349	127	568	421	147	657	501	156	714
Fusion	25	18	7	34	23	11	42	36	6	51
Geothermal	1	1	2	2	3	6	7	13	13	10
Solar	2			7			18			35
Conservation and utilization	67	8	59	20	8	12	54	9	45	60
All other				76	14	62	100	30	70	116

[1] Includes all sources other than the Federal Government.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), p. 59, and *Science Resources Studies Highlights*, "Energy Increase of 18 Percent Paces Industrial R&D Spending in 1975", October 27, 1976 (NSF 76-324).

funds rose from 60 percent of the total in 1974 to 83 percent in 1975. Companies' own funds go into the development of oil more than any other energy source. In 1973 industry spent 48 percent of all its own energy R&D funds in this area; this figure dropped to 41 percent in 1975.

Spending for pollution abatement R&D rose by an estimated 10 percent over the 1973-76 interval (Table 4-9), less than the inflation rate. Most of the increase was between 1973 and 1974; there was a drop from 1974 to 1975. The largest increases, both in percent and absolute terms, were recorded in the aircraft, chemical, and "other" manufacturing industries, while there was a decrease in funding by the motor vehicles industry and nonmanufacturing industries. Still, more than half of all pollution abatement expenditures occur within the motor vehicles industry.

Federal support of pollution abatement R&D in industry has amounted to only 6 to 8 percent of the total in recent years (Table 4-10). Air pollution consistently receives about three-fourths of all funding, while three-fourths of this in turn is devoted to automotive emissions. The expenditures on emissions R&D are virtually the same as those shown for the motor vehicles industry on Table 4-9, as would be expected. The greatest fractional change was in solid waste R&D, which more than doubled from its relatively low figure in 1973 to the estimated 1976 expenditure.

Allocation of expenditures to basic research, applied research, and development

Business enterprises, of necessity, are primarily output oriented. This is reflected throughout the wide spectrum of activities carried on by industrial firms, including their R&D activities, and explains why such factors as risk and expected time to payoff play such an important role in setting firms' R&D policies. Although the proportion differs somewhat among individual industries, the result of this management policy for industry as a whole is a relatively heavy investment in development, at times approaching four-fifths of total industrial R&D spending, and a lighter investment in research, of which only a small part, usually 3 to 4 percent of total R&D spending, goes for basic research (Figure 4-11). Furthermore, in times of financial strain, firms generally lean even more toward the lower risk, quicker payoff R&D projects. It should be noted, however, that of the relatively small amount devoted to research, only one-fourth was federally funded in 1976,

4-9. Industrial R&D expenditures for pollution abatement, by industry, 1973-76

(Dollars in millions)

Industry	1973	1974	1975	1976 (est.)
All industries	$603	$657	$651	$663
Electrical equipment and communication	13	16	17	15
Petroleum refining and extraction	51	61	66	60
Aircraft and missiles	25	34	37	37
Chemicals and allied products	55	65	71	77
Motor vehicles and motor vehicle equipment	380	384	347	356
Other manufacturing industries	44	70	79	86
Nonmanufacturing industries	35	27	34	32

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), p. 60, and *Science Resources Studies Highlights*, "Energy Increase of 18 Percent Paces Industrial R&D Spending in 1975", October 27, 1976 (NSF 76-324).

4-10. Industrial R&D expenditures for pollution abatement, by type of pollution and source of funding, 1973-76

(Dollars in millions)

Year	Source	All types	Type of pollution: Air pollution: All	Automotive emissions	Other	Water	Solid Waste	Water or Solid Waste	Other types
1973	Total	$603	$461	NA	NA	$76	$10	$86	$56
	Federal	35	10	NA	NA	NA	NA	4	21
	Company[1]	568	451	NA	NA	NA	NA	82	35
1974	Total	657	508	$383	$125	60	14	74	75
	Federal	51	17	NA	NA	NA	NA	5	29
	Company	606	491	NA	NA	NA	NA	69	46
1975	Total	651	482	345	137	71	22	93	76
	Federal	44	16	NA	NA	NA	NA	5	23
	Company	607	466	NA	NA	NA	NA	88	53
1976	Total (est.)	663	492	361	131	76	21	97	74

[1] Includes all sources other than the Federal Government.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), p. 60, and *Science Resources Studies Highlights*, "Energy Increase of 18 Percent Paces Industrial R&D Spending in 1975", October 27, 1976 (NSF 76-324).

according to estimates (Figure 4-12). This compares with 1965, when about 40 percent of industry's research was funded by the Government. The portion of development supported by Federal funds also went down, from 60 percent in 1965 to about 40 percent in 1976.

The tendency of industry since 1960 has been toward investing in applied research and even more toward development, as is evident from the trend lines shown in Figure 4-11. The estimated constant dollar increases in R&D funding from 1960 to 1976 were 6 percent for basic research, 21 percent for applied research, and 33 percent for development.

Applied research and development by product field

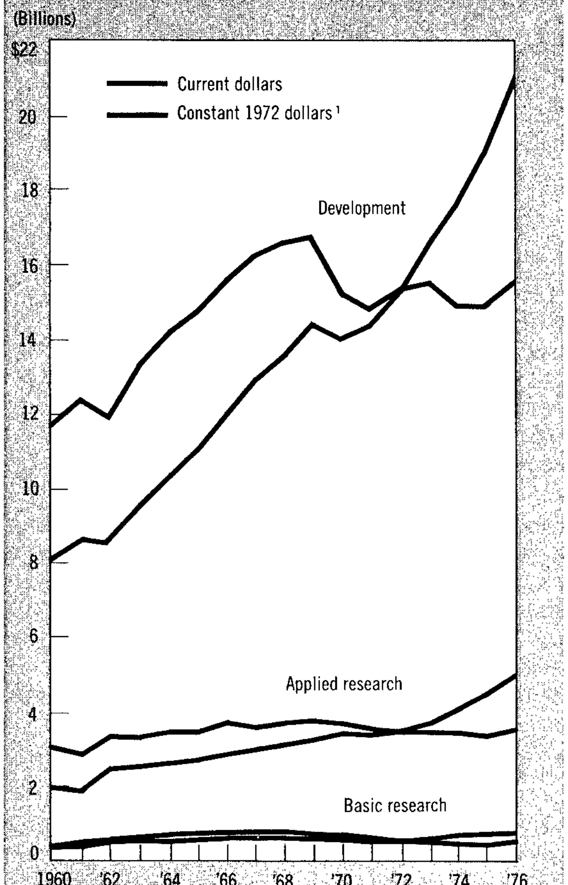
In some respects, it is more informative to examine trends in applied research and development expenditures by product field than by industry group in assessing industrial R&D performance.[10] When expenditures are reported by industry group, all the R&D performed by a corporation is assigned to the single industry under which that corporation is classified. However, existing data permit the R&D performed by a corporation to be allocated among that corporation's various product fields. Consequently an analysis of R&D expenditures according to product fields gives a more refined description of the allocation of such funds.

Product fields, like industries, are classified in terms of the Standard Industrial Classification. Seventeen broad fields are distinguished. Some of these are subdivided, so that the subdivisions added to the undivided broad product fields make up 29 narrow fields. A complete list of fields is given in Appendix Table 4-8.

[10] Expenditures for basic research are excluded here since such research, by definition, is not directed toward specific products.

4-11

Industrial R&D expenditures for basic research, applied research, and development, 1960-76



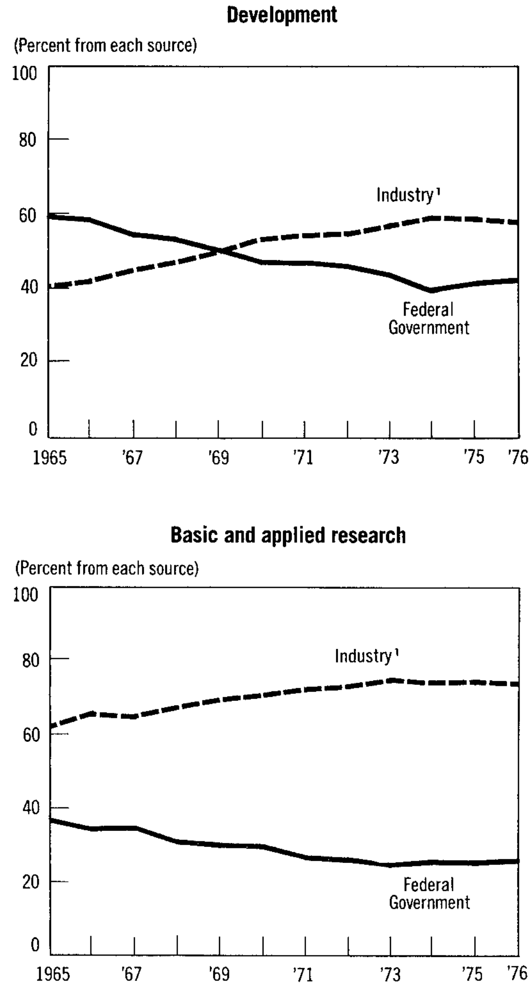
[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Estimates are shown for 1975 and 1976.

REFERENCE: Appendix Table 4-6.

4-12

Percent distribution of research expenditures and development expenditures in industry by source of funds, 1965-76



[1] Includes all sources other than the Federal Government.

NOTE: Estimates are shown for 1975 and 1976.

REFERENCE: Appendix Table 4-7.

More than two-thirds of total applied research and development expenditures in 1974 went into only 6 of the 17 broad product field categories. The six fields and their respective shares are shown in Table 4-13.

Of the 29 narrow product field categories, 17 experienced changes in constant dollar funding levels of 15 percent or more during the 1971-74 period. These fields are shown in Table 4-14 grouped according to size of increase or decrease.

Distribution of industrial R&D by size of company

Besides being mainly concentrated in only five or six industries, industrial R&D is further concentrated within a small number of large companies, i.e., companies with more than 10,000 employees. In 1974, 309 of these companies accounted for 84 percent of all industrial

4-13. Distribution of applied research and development expenditures to broad product fields with the greatest shares, 1974

Broad product field	Percent of funds to all product fields
Communication equipment and electronic components	18
Machinery	12
Guided missiles and spacecraft	11
Aircraft and parts	11
Motor vehicles and other transportation equipment	10
Chemicals[1]	7
Total	69

[1] Except drugs and medicines.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), p. 68.

R&D expenditures; the total number of R&D-performing companies is estimated at more than 11,000. The 20 leading companies spent 53 percent of the 1974 total.[11] At this level of concentration, the R&D activities of a single firm can significantly affect the overall level of industrial R&D effort.

Industries vary widely in the extent to which their R&D is concentrated. To consider only the six leading R&D-performing industries, the motor vehicles industry had 94 percent of its R&D expenditure concentrated in the top four companies in 1974; this figure was 66 percent in the instruments industry, 55 percent in electrical equipment and communication, 54 percent in aircraft and missiles, 43 percent in machinery, and 33 percent in chemicals.

A discussion of the distribution of R&D expenditures would be incomplete without some mention of small "high technology" firms. This group of research-based enterprises accounts for a small portion of total industrial R&D spending. However, they are responsible for a substantial contribution to science and technology and are considered by many to be more efficient performers of research and development than large companies.[12]

Moreover, there is some evidence that such companies are also more effective in producing new jobs. A sample group of five "young high-technology companies" was found to increase its aggregate sales at a rate of 43 percent compounded per year, from 1969 to 1974. In the same interval, six "mature companies" increased their sales by 11 percent per year. However, employment in the young companies increased by 41 percent per year during that time, while that in the mature companies increased only 1 percent.[13] A possible reason for this is that more

[11] *Research and Development in Industry, 1974*, National Science Foundation (NSF 76-322), p. 37.

[12] For further information on R&D in small companies, see Thomas Hogan and John Chirichiello, "The Role of Research and Development in Small Firms", in *The Vital Majority: Small Business in the American Economy*, Small Business Administration, 1974.

[13] *The Role of New Technical Enterprises in the U.S. Economy: A Report of The Commerce Technical Advisory Board to the Secretary of Commerce*, Department of Commerce (January 1976), p. 14.

4-14. Percent change in constant dollar applied research and development expenditures for narrow product fields with greatest changes, 1971-74

Increases of more than 25 percent		Increases of 15-25 percent		Decreases of 15 percent or more	
Transportation equipment (except motor vehicles)	58	Electrical industrial apparatus	24	Guided missiles and spacecraft	-28
Engines and turbines	36	Office, computing, and accounting machines	23	Metalworking machinery and equipment	-26
Textile mill products	35	Farm machinery and equipment	19	Nonferrous metals and products	-22
Professional and scientific instruments	32	Rubber and miscellaneous plastics products	19	Aircraft and parts	-21
Motor vehicles and equipment	26	Construction, mining, and materials handling machinery	17	Agricultrual chemicals	-15
		Petroleum Refining and extraction	15		
		Ferrous metals and products	15		

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), p. 68.

mature and larger corporations tend to reduce employment via such mechanisms as improved productivity. Since the sample taken was so small, these numbers have only suggestive value.

The history of high technology companies founded since World War II suggests that it is in the Nation's interest that such companies continue to be established. Therefore it is a matter of concern that fewer and fewer small high-technology companies are being founded every year. One measure of this is the number and aggregate funding of new technical companies that are publicly financed, as shown on Table 4-15.

4-15. New publicly financed small technical companies

Year	Number	Funding (in millions)
1969	204	$349
1970	86	149
1971	73	138
1972	104	194
1973	19	38
1974	4	6
1975 (first 6 months)	0	0

SOURCE: Department of Commerce, *The Role of New Technical Enterprises in the U.S. Economy: A Report of the Commerce Technical Advisory Board to the Secretary of Commerce* (January 1976), p. 15.

R&D intensity of manufacturing industries

The proportion of an industry's human and financial resources which is utilized for R&D may be regarded as a measure of the "R&D intensity" of that industry. Indices that may be used for quantifying the level of R&D intensity are: the number of R&D scientists and engineers per 1,000 employees and the total and company R&D funds as a percentage of net sales. As stated earlier in this chapter, the level of R&D effort varies considerably among industries and among companies within an industry. Further evidence of this variation is contained in Table 4-16 which shows the three indices of R&D intensity for the 15 major classes of manufacturing industries. These indices provide a basis for dividing the 15 industries into three distinct groups, where each is separated from the next by a factor of approximately three with respect to each measure of R&D intensity. The relative sizes of these three groups are indicated by the fact that the total net sales by Group I industries over the 1961-74 period were 23 percent above the sales by industries in Group II and 48 percent above Group III sales.[14]

During the 1961-74 period, each of the indices for Groups II and III, as shown in Figure 4-17, remained fairly constant or declined slightly. For Group I, however, two of the indices show a substantial drop. The primary reason for this drop is the reduction in Federal support of industrial research and development after the mid-1960's that was indicated above on Figures 4-1 and 4-3.

[14] The "other" manufacturing industries, excluded from this table, had net sales roughly 10 percent of Group I net sales in this period. Net sales figures are not available for the nonmanufacturing industries reporting considerable expenditures for R&D.

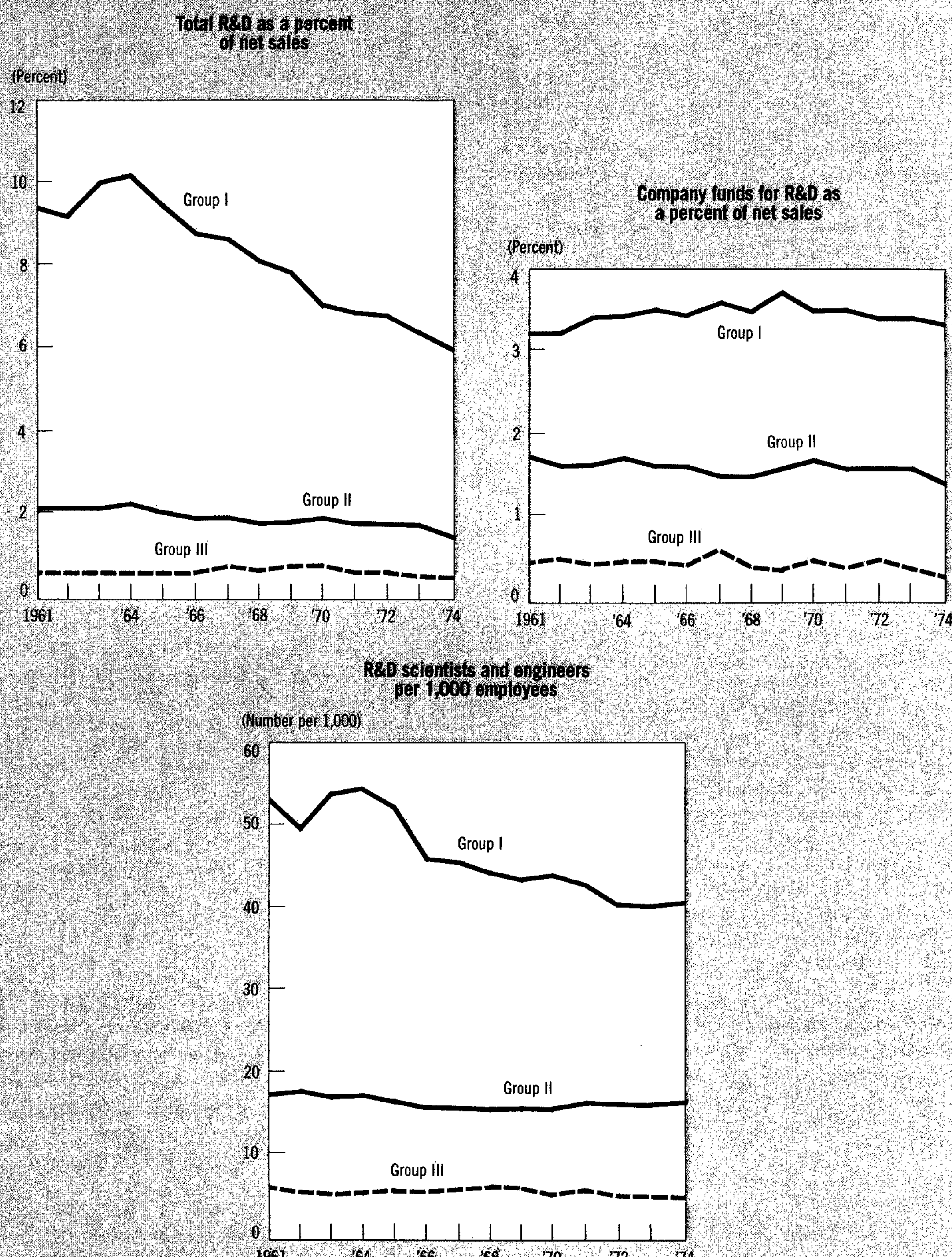
4-16. Measures of R&D intensity, by industry, 1961-74

Manufacturing industry	Mean over the 1961-74 period		
	R&D scientists and engineers per 1,000 employees	Total funds for R&D as a percent of net sales	Company funds[1] for R&D as a percent of net sales
Group I			
Chemicals and allied products	37.8	3.8	3.4
Machinery	26.1	3.9	3.2
Electrical equipment and communication	46.1	8.2	3.6
Aircraft and missiles[2]	85.4	19.1	3.3
Professional and scientific instruments	33.8	5.8	4.2
Mean for Group I	46.1	7.7	3.4
Group II			
Petroleum refining and extraction	15.8	.8	.8
Rubber products	17.4	1.9	1.6
Stone, clay, and glass products	10.8	1.6	1.5
Fabricated metal products	12.2	1.3	1.2
Motor vehicles and other transportation equipment	19.8	3.3	2.6
Mean for Group II	14.4	1.9	1.2
Group III			
Food and kindred products	7.1	.4	.4
Textiles and apparel	3.1	.5	.4[3]
Lumber, wood products, and furniture	5.0	.5	.4[3]
Paper and allied products	8.3	.8	.8[3]
Primary metals	5.5	.7	.7
Mean for Group III	6.0	.6	.4

1 Includes all sources other than the Federal Government.
2 Includes ordnance.
3 Data for company funds are not available for several years. Mean computed using only those years for which data are available.

4-17

R&D intensity of U.S. manufacturing industries, 1961-74



REFERENCE: Appendix Table 4-9.

OUTPUTS FROM INDUSTRIAL R&D

The preceding sections of this chapter have dealt with inputs to the R&D portion of the innovation process in industry. All of the resulting indicators have described the dollars or manpower devoted to industrial R&D. The sections that follow show some attempts to measure the output from the innovation process. Indicators of this kind are much more difficult to develop; no units as simple as dollars or persons employed are readily available to measure outputs. The discussion presented here represents an early stage in the development of such output indicators.

Two kinds of indicators will be discussed: Patents will serve as a measure of inventions produced in industry. The year-to-year production of patented inventions is analyzed according to inventor, assignee, and product field. Innovations themselves are studied by analyzing a sample of major innovations in terms of such variables as their radicalness, the year of market introduction, the size of the innovating company and the industry it belongs to, the R&D intensiveness of that industry, and the source of the technology underlying the innovation.

Future work is expected to improve upon the output indicators presented here. Many of the benefits to industry from R&D are neglected, such as reduced costs, greater output, or higher quality in the production of existing products. The present indicators, furthermore, do not directly relate outputs to their corresponding inputs. For example, it would be very helpful to know the relationship between the rate of patented invention and the resources expended for the R&D that leads up to invention. To find such relationships it may prove necessary to develop explicit models for invention and for the whole innovation process. Such models would have to allow for many other inputs to the innovation process in addition to R&D dollars and manpower.

By the same token, technological innovation is not the only factor affecting productivity and economic growth. Because so many other factors intervene, no indicators are given here of the effect of innovation on productivity and economic growth in general. In lieu of quantitative indicators of this relationship, the final section of this chapter presents some conclusions drawn from studies that have been done in this area.

Finally, the indicators in this chapter do not include measures of the negative results or side-effects of technological innovation. These costs may be extensive in personal and social terms, ranging from the loss of jobs to pollution of the environment. The determination of these costs and their assessment relative to benefits is necessary for the wise management of innovation. Valid indicators of these costs, however, are exceedingly difficult to develop because they require a rather precise relating of causes with effects. Such models must depend on a great deal of additional research.

Patented inventions

Invention is an essential stage in the innovation process. It consists in the demonstration of a new technical idea by the building and testing of a working model of a new device or process, or a usable batch of a new material. The idea thereby becomes suitable for patenting. Hence the number of patents produced in a given technological area, or by a certain source, can serve as an indicator of the level of technological activity there and of its success. Of course, the number of patents may in some cases understate the actual level of invention. For various reasons an invention may never be patented as, for example, when the protection afforded by a patent is less important than the rapid introduction of a new product into the market place, or when the expected protection does not offset the hazard of disclosure. In other cases, patent output may overstate the level of invention, as when numerous defensive patents are obtained around a basic invention, or when a competitor establishes a nuisance patent that makes it difficult for the originator to develop the invention without obtaining a license from him. Finally, patents differ greatly in their economic and social significance. Only a fraction of all patented inventions become embodied in new and improved products, processes, and services, and only some of these eventually produce substantial economic or social returns.

The majority of patented inventions now come from research performed within the R&D programs of large industrial corporations. Many of the others, including some very significant ones, come from independent inventors. In any case, patented inventions constitute a major resource for technology-based industries, which use them as the input for the subsequent stages

of development, manufacturing start-up, and marketing. In this sense, inventions are an input to the innovation process, as much as an output.

Patent output by inventor and assignee. The number of patents granted by the United States in a given year is a measure of inventive activity in a somewhat earlier period, since roughly 2 years are required for processing and examining of patent applications by the U.S. Patent Office. Figure 4-18 shows the total number of patents granted in each year from 1960 to 1976. This number shows significant fluctuation from year to year, some of which is due to variations in the rate of Patent Office processing, but there is a clear overall increase from 1960 to 1971, with a decline thereafter.

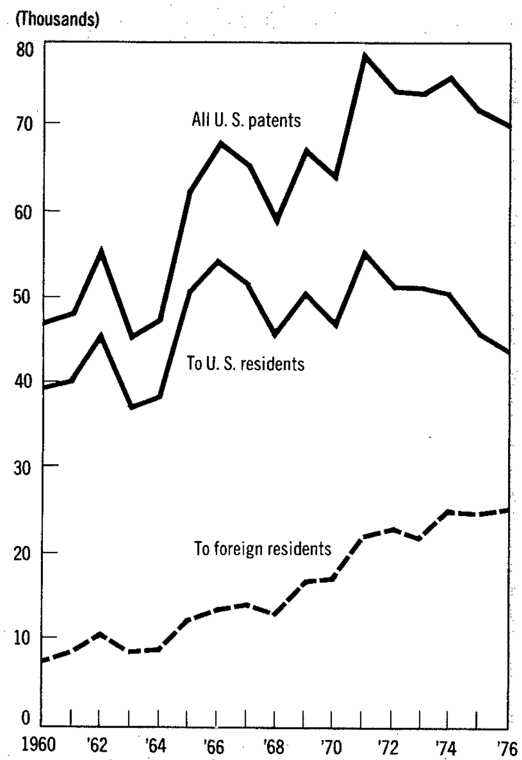
The figure also shows the number of U.S. patents granted in each year to inventors who were residents of the United States and to inventors residing in other countries. The number of foreign inventions patented in the United States has increased with considerable consistency throughout the period from 1960 to 1976. On the other hand, the number of patents granted to U.S. inventors reached a peak in 1971 and has declined steadily since. In 1976 this number was below the level for any year since 1965. The decrease in U.S. inventions accounts for the decline in the total number of patents since 1971, which was noted above.

When a patent is granted, it is sometimes owned by the inventor, but very often it is assigned to some other owner. For example, an employee of a corporation or a contractor will frequently allow his patented invention to be assigned to the corporation that supported his research. Similarly, patents are often assigned to the U.S. Government if the underlying research was done in an inhouse R&D facility of a Government agency, or by a university or corporate laboratory working under a Government grant or contract. Counts of patent assignments therefore give an indication of the professional affiliation of inventors.

On Figure 4-19, the patents granted to U.S. inventors are further subdivided according to the four classes of owners to which they were assigned, for each year from 1961 to 1976. U.S. corporations were by far the most frequent assignees,[15] with about 70 percent of the patents in any year. U.S. individuals were assigned most of the remainder, from 20 to 30 percent in any one year. The corporations' share may actually be larger than is shown, since "U.S. individuals" includes patents that are not assigned on the date of issue. A few of these are later assigned to corporations. Still, it is clear that the drop in patenting due to U.S. inventors beginning in 1971 is largely due to a drop in corporation patenting activity. However, ownership by individuals has also been decreasing since 1974.

4-18

U. S. patents granted, by inventor and date of grant, 1960-76



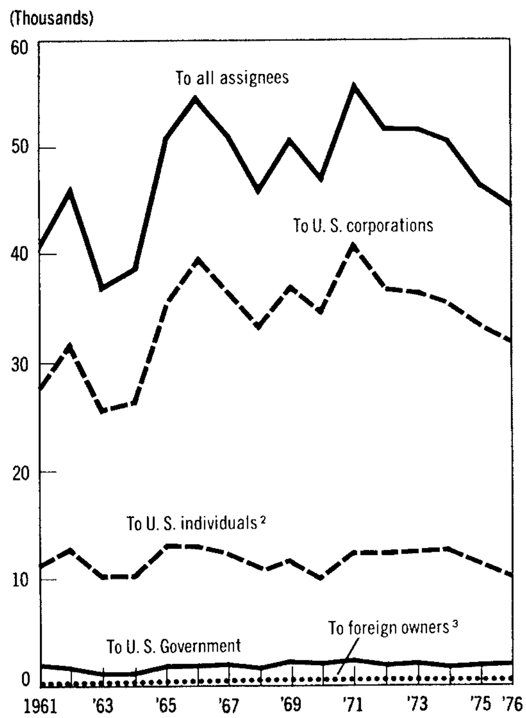
REFERENCE: Appendix Table 4-10.

Patent output by field of invention. It is of interest to know the distribution of patents among various industries, since this can serve as an indicator of the level of invention in those industries, under the limitations noted above. The files of the Patent Office do not allow this distribution to be determined directly, since they

[15] A recent report, *A Review of Patent Ownership*, Office of Technology Assessment and Forecast, U.S. Patent Office, January 1975, identified specific companies involved in active technological areas.

4-19

U. S. patents[1] granted, by assignee and date of grant, 1961-76



[1] Due to U. S. inventors.
[2] Comprises patents assigned to U. S. individuals and unassigned patents.
[3] Comprises patents assigned to foreign corporations, governments, and individuals.
REFERENCE: Appendix Table 4-11.

classify patents according to the nature of the material or device patented, rather than according to industry. However, a concordance has recently been developed by the Patent Office that permits about 95 percent of all patents granted by the United States from 1963 to 1975 to be apportioned among 52 classes of manufacturing industries.[16] The concordance is based on the general judgment of Patent Office personnel as to which industries are most likely to produce patentable devices or materials of a given kind. At this stage of its development it does not take account of the actual companies or industries that own the patents. Instead, it in effect classifies patents in terms of their product fields, which are described earlier in this chapter.

[16] *Indicators of the Patent Output of U.S. Industry, II*, Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, 1976. (A study commissioned specifically for this report.)

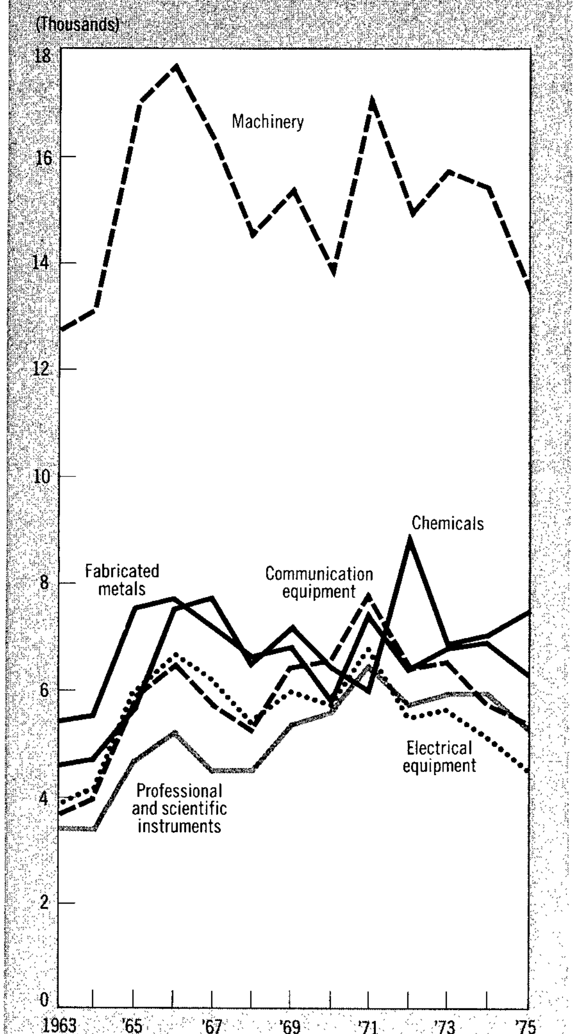
The concordance allots a certain kind of device to more than one product field if it seems to be applicable to more than one. Hence a patent for such a device will be allotted to more than one product field, and so will be counted more than once. The multiple counting of patents may lead to a single patent being allotted to two or more narrow product fields under the same broad product field. However, in such a case the broad product field will receive only one count. The result of this is that patent counts in narrow product fields do not in general add up to the counts in their inclusive broad product field class, nor can the broad fields be combined to give the total number of patents granted. It should be noted that the product fields used in the concordance do not exactly correspond with the industry classes used elsewhere in this chapter.

Appendix Table 4-12 shows the number of U.S. patents due to U.S. inventors and allotted to each of the 52 narrow product fields, for each year from 1963 to 1975. The data for the six broad product fields with the most patents also appear in Figure 4-20. The number of patents produced in each field depends to some extent on the way in which the fields are defined. Beyond this, however, the figure shows that in most of the six fields there has been little if any growth in the rate of patenting since 1965. This is consistent with the behavior of the total number of U.S. patents due to U.S. inventions as shown in Figure 4-18.

Appendix Table 4-12 also shows the average yearly increase or decrease in the rate of patenting for each field in the interval from 1963 to 1975.[17] Among the fields shown in Figure 4-20, professional and scientific instruments had the greatest growth rate, 3.9 percent per year. The chemical field was second with 2.8 percent per year. Among the narrow product fields, soap and detergents had the highest growth rate at 6.7 percent per year. The other leaders were also within the chemical or drug fields. The greatest decrease between 1963 and 1975 occurred in guided missiles and space vehicles, which lost an average 4.0 percent per year in their rate of patenting. Other losses occurred in the household appliance and the motorcycle and bicycle fields.

[17] This is found from the slope of the least-squares line, which is the straight line that best fits the data for each product field, from 1963 to 1975. The least-squares line is used because it removes the effect of stray year-to-year fluctuations.

4-20
U. S. patents[1] granted, in selected major product fields, by date of grant, 1963-75



[1] Due to U. S. inventors.
REFERENCE: Appendix Table 4-12.

Patent output by inventor, assignee, and field of invention. The distribution of patents granted can be further analyzed by considering simultaneously inventors or owners and product fields. Thus Table 4-21 shows the level of foreign invention for those narrow product fields that had the highest and lowest percentages of foreign invention in 1975. Comparison is made with the percentage of foreign invention in the same fields in 1965, and actual patent counts are also shown for both years. Corresponding information for all product fields can be found in Appendix Table 4-13.

Some of the fields in which foreign invention is prominent, such as motorcycles and bicycles, are quite small. Others, however, like drugs and industrial organic chemicals, are very substantial. The product fields in which foreign patenting in the United States is relatively low also include some major fields. However, for every product field shown, foreign patenting has increased in relative terms since 1965. The actual patent counts serve to show the reasons for this. In some cases, namely drugs and industrial organic chemicals, U.S. patenting actually increased between 1965 and 1975, but foreign patenting increased so much faster that the percent due to foreign inventors went up. In the other cases, the number of patents to U.S. inventors dropped from 1965 to 1975. In the case of ordnance and miscellaneous chemical products, foreign patenting also dropped, but U.S. patenting dropped even more in relative terms.

Similarly, for those inventions that are due to U.S. inventors, it is possible to show the ownership of patents in the various product fields. U.S. corporations are the owners of most of such patents, as Figure 4-19 shows. Table 4-22 indicates the particular product fields in which ownership by U.S. corporations was greatest and least in 1975. The percent ownership by U.S. corporations in 1965 is also tabulated for the same fields. The five fields with the greatest corporation ownership are all related to chemicals. The fields with the lowest ownership by corporations had exceptionally high levels of ownership by the U.S. Government or U.S. individuals as the following tables indicate.

Table 4-23 shows the product fields with the greatest percentage ownership of U.S. patents by the Federal Government. Ordnance clearly leads the other fields, and the percentage of Government ownership of these patents has increased from 32 to 42 percent between 1965 and 1975. According to Appendix Table 4-14, which includes the distribution of ownership for all product fields, there was a corresponding drop in ownership by U.S. individuals in this field. The fields of greatest ownership by U.S. individuals are listed on Table 4-24. U.S. individuals have the greatest share of the patents in fields related to transportation and machinery.

4-21. Sources of invention for U.S. patents, for product fields with the highest and lowest percentages of foreign inventions in 1975

Product field	Percent foreign inventors		Number of patents granted			
			U.S. inventors		Foreign inventors	
	1965	1975	1965	1975	1965	1975
Highest percent foreign:						
Motorcycles, bicycles, and parts	34	49	103	73	53	69
Drugs	42	46	580	1,140	423	968
Railroad equipment	24	46	624	451	202	390
Industrial organic chemicals	31	45	2,826	3,650	1,248	2,965
Aircraft and parts	30	45	833	821	353	659
Primary and secondary nonferrous metals industries	29	45	325	308	132	251
Lowest percent foreign:						
Household appliances	18	29	1,039	792	222	316
Farm and garden machinery and equipment	18	27	1,871	1,500	401	561
Ordnance, except missiles; and tanks	17	27	403	83	327	123
Miscellaneous chemical products	15	27	415	76	519	196
Oil and gas extraction, and petroleum refining and related industries	7	16	784	761	62	150

REFERENCE: Appendix Table 4-13.

4-22. Percent of U.S. patents[1] owned by U.S. corporations, in product fields with the highest and lowest percentages in 1975

Product field	Percent of patents in each product field[2]	
	1965	1975
Highest percent corporation—owned:		
Plastic materials and synthetic resins, rubber, and fibers	95	93
Industrial organic chemicals	94	92
Oil and gas extraction, and petroleum refining and related industries	92	90
Drugs	89	89
Agricultural chemicals	87	89
Lowest percent corporation—owned:		
Construction, mining, and materials handling machinery and equipment	61	63
Miscellaneous transportation equipment	66	62
Farm and garden machinery and equipment	53	56
Ship and boat building and repairing	54	49
Ordnance, except missiles; and tanks	38	39

[1] Due to U.S. inventors.
[2] By date of patent grant.

REFERENCE: Appendix Table 4-14.

4-23. Percent of U.S. patents[1] owned by U.S. Government, in product fields with the highest percentages in 1975

Product field	Percent of patents in each product field[2]	
	1965	1975
Ordnance, except missiles; and tanks	32	42
Guided missiles and space vehicles and parts	16	15
Miscellaneous chemical products	6	14
Electronic components and accessories and communication equipment	7	9
Radio and television receiving equipment, except communication types	6	9
Electrical transmission and distribution equipment and electrical measuring instruments	5	9
Textile mill products	3	9

[1] Due to U.S. inventors.
[2] By date of patent grant.

REFERENCE: Appendix Table 4-14.

4-24. Percent of U.S. patents[1] owned by U.S. individuals, in product fields with the highest percentages in 1975

Product field	Percent of patents in each product field[2]	
	1965	1975
Ship and boat building and repairing	44	44
Farm and garden machinery and equipment	46	43
Miscellaneous transportation equipment	33	37
Construction, mining, and materials handling machinery and equipment	38	36
Refrigeration and service industry machinery	33	35

[1] Due to U.S. inventors.
[2] By date of patent grant.

REFERENCE: Appendix Table 4-14.

Patent output in active patent fields. A special study was made of 30 fields that showed especially high patenting activity in the 1973-75 period. They were so chosen that six of these patent fields would fall under each of the five manufacturing industries in R&D Intensity Group I.[18] The 30 active patent fields can be considered as a group and compared with all patents granted, as in Table 4-25. The percent foreign invention and the ownership are compared, for patents granted in 1975. The most active fields have a significantly greater percentage of foreign invention than do all U.S. patents taken together. There is also a very significant difference in ownership patterns. More patents in the most active fields are owned by U.S. corporations, while U.S. individuals own considerably fewer of them.

[18] A list of these 30 active patent fields appears in the first chapter of this report, "International Indicators of Science and Technology".

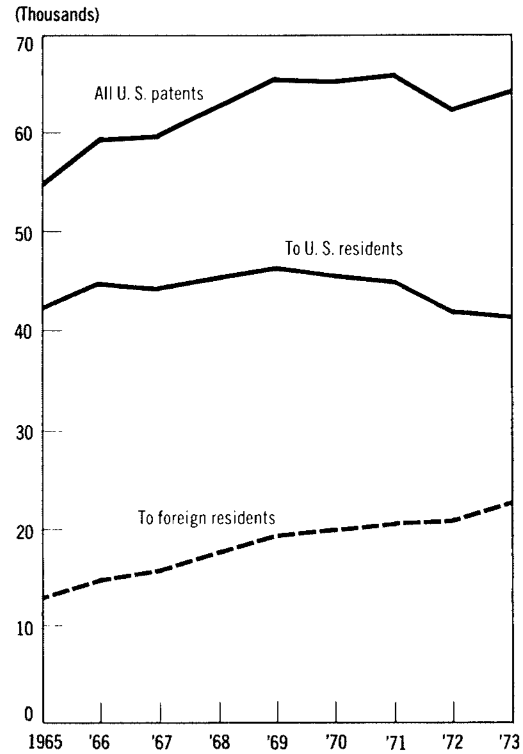
4-25. **Invention and ownership of patents granted in 30 active patent fields, and of all U.S. patents granted in 1975**

Invention or ownership	Percent of patents: 30 active patent fields	All U.S. patents
Foreign invention	43	35
U.S. corporation ownership of U.S. inventions	89	71
U.S. Government ownership of U.S. inventions	3	4
U.S. individual ownership of U.S. inventions	7	24
Foreign ownership of U.S. inventions	1	1

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *U.S. Patent Activity in Six R&D Intensive Industries* (1976), (a study commissioned specifically for this report), and Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *OTAF Special Report—All Technologies* (May 1977), unpublished.

4-26

U. S. patents granted, by inventor and date of application, 1965-73



REFERENCE: Appendix Table 4-15.

Patent output by date of application. It has been noted that patents counted according to date of grant reflect inventive activity in an earlier period because there are delays in the processing of applications by the Patent Office. Also, fluctuations are introduced into the counts by variations in this processing. Some data are available to show patent counts by date of *application* for patents that are subsequently granted. Figure 4-26 is an example. It shows total counts for U.S. patents and divides this count according to U.S. and foreign inventors. Thus it corresponds to Figure 4-18 earlier in this chapter. Data are reliable only for the interval from 1965 to 1973, which is more narrow than the interval covered by Figure 4-18. It should be noted that a few patents that were applied for in these years may yet be granted. If so, they will add only slightly to the counts shown for these years.

As the figure indicates, there is much less fluctuation from year to year when application dates are used, rather than grant dates as on Figure 4-18. The total number of applications that were later granted reached a peak in 1971. Applications from U.S. inventors reached a peak in 1969 and also fell significantly after 1971. On the other hand, applications from foreign inventors increased in every year after 1965.

For the patents granted to U.S. inventors, a further analysis can be made of patent *ownership* by year of application. This is shown on Figure 4-27. It corresponds to Figure 4-19, which shows the ownership of patents due to U.S. inventors by year of patent grant. U.S. corporations, which have the largest share, had their greatest number of successful applications in 1969. The greatest number of *grants* to U.S. corporations occurred in 1971, according to Figure 4-19. This shows the effect of the 2-year delay in the processing of applications. Patents assigned to the U.S. Government reached their maximum in 1969 and have declined steadily since. Patents assigned to U.S. individuals reached a peak in 1970.

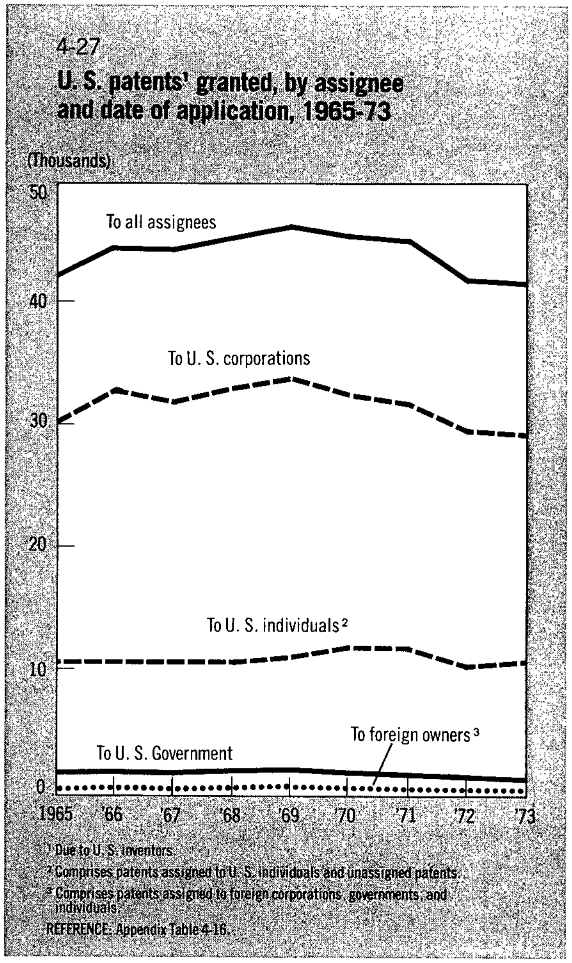
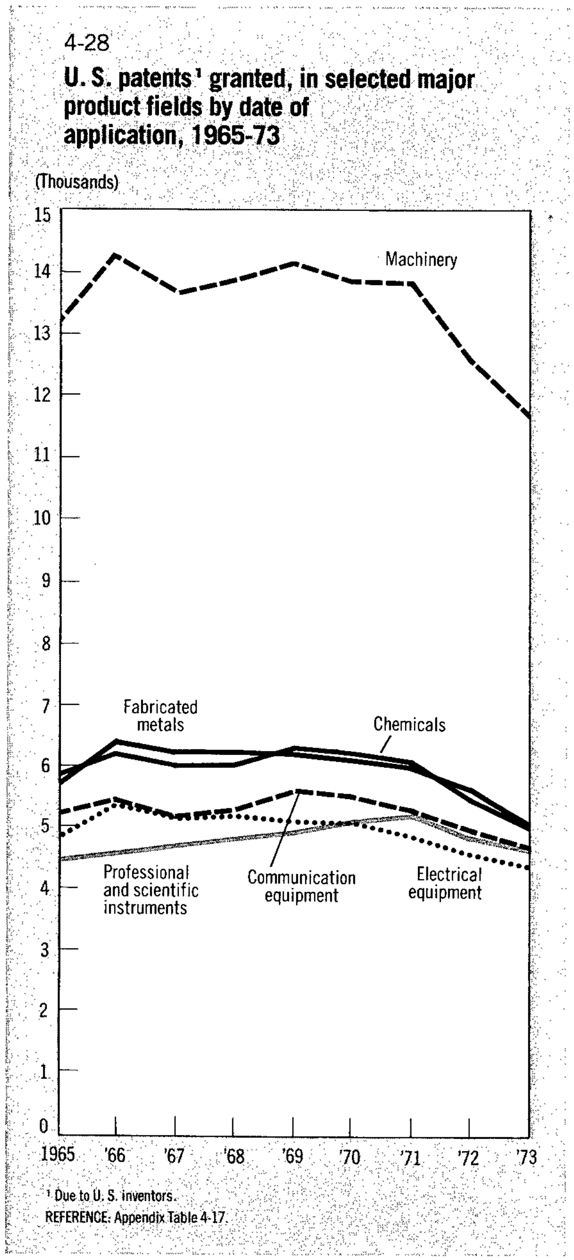


Figure 4-28 shows patent activity by date of application for the six major product fields shown on Figure 4-20 above. Data for all fields are given in Appendix Table 4-17. In the shorter period represented by Figure 4-28, patenting in each of the selected major product fields goes through a maximum in some year from 1966 to 1971. As the Appendix Table indicates, U.S. patenting dropped in nearly every product field from 1971 to 1973, in terms of date of application. The only exceptions were in agricultural chemicals; drugs; and motorcycles, bicycles, and parts.

Technology and innovation

Innovation, as here understood, is the introduction of new or improved products, processes, or services into the market. Technological innovation involves new technology or new applications of technology, and therefore is commonly a product of R&D. Hence the rate of production of technological innovations by certain industries or industry groups, or by the whole Nation, can serve as a measure of the success of the R&D effort of that aggregate in a given period. At the same time, it must be recognized that the rate of R&D-based innovation does not depend on R&D expen-



ditures alone, but is strongly affected by such other factors as the availability of capital and government regulatory policy. Even if an invention has been created, and development has produced a workable process by which a suitable version of the invention can be put into commercial production, the introduction of the product into the market may be deterred by the high costs of manufacturing start-up or by the costs and risks involved in establishing a new market. Moreover, the diversion of R&D funds into "defensive research", such as research to insure that products and processes comply with requirements imposed by government, may sometimes reduce the number of genuine innovations.

Indicators of U.S. technological innovation were developed on the basis of a study of major technological innovations that were introduced into the U.S. commercial market during the period 1953-73. All are products or processes, rather than services, and were selected for their importance by a rating panel.[19] The panelists were asked to consider the specific innovation and its technological consequences, as well as its primary and secondary impacts in socio-economic and political terms. Thus the innovations that were studied are not representative of the great number of industrial innovations that are only minor modifications of existing products and processes.

The sample studied contained 277 innovations marketed by U.S. manufacturing companies. All of these companies belonged to one of the manufacturing industries listed earlier in this chapter; hence each innovation could be assigned to one of the three R&D intensity groups of manufacturing industries. In addition, there were 42 innovations introduced by U.S. non-manufacturing industries. Of these, 33 came from industries for which R&D expenditure data are available because they spend significant amounts for R&D. Hence there were 310 innovations that could be used to measure R&D output.

Table 4-29 gives a selection of the innovations that were studied, arranged according to the industry that introduced them into the market. The list shows that the innovations considered were highly diverse. The set of 310 innovations from which these were taken may be considered a representation of all major U.S. innovations in the 1953-73 period. Hence the distributions of these innovations that are discussed below may be taken to apply to all major innovations in this period. In this way general conclusions can be reached about U.S. innovative activity. It should be recognized, however, that no test has been made of the validity of this sample as a representation of all major innovations. Hence some caution is required in interpreting these indicators.

Innovation and company size. The size of the innovating company is a variable that importantly affects the number of major innovations that the company produces. This subject was examined by studying the set of major innovations described above. Figure 4-30 shows the percent of the innovations studied that were produced by companies in each of five size categories and in each of three time periods. Company size is measured in terms of total number of employees. These results show that large companies (those with 10,000 or more employees) produced the greatest proportion of major innovations, followed by firms in the two smallest size categories (up to 100, and 100 to 1,000 employees). The data also show that the number of innovations from large companies has increased over time, in both absolute and relative terms. On the other hand, if all firms with up to 1,000 employees are called "small firms", then small firms produced more major innovations than large firms in the 1953-59 and 1960-66 periods, and an equal number in the 1967-73 period. Overall, however, the distribution of innovations by company size does not change greatly from one time period to another.

The effect of company size will be clearer if the different groups of companies based on size can be reduced to comparable terms. The various size groups contained different numbers of firms, and put different levels of effort into R&D. This will account for much of the variation in their outputs of innovations.

One way to remove this factor would be to divide the total number of major innovations produced by each size group in each time interval by the corresponding number of dollars that that group spent on R&D in that interval. The result would be the innovation rate, in innovations per dollar, for each group in each interval. With available data it is possible to make an estimate of this rate by dividing the number of innovations

[19] See *Indicators of International Trends in Technological Innovation*, Gellman Research Associates, 1976.

4-29. Examples of major U.S. technological innovations studied, by industry

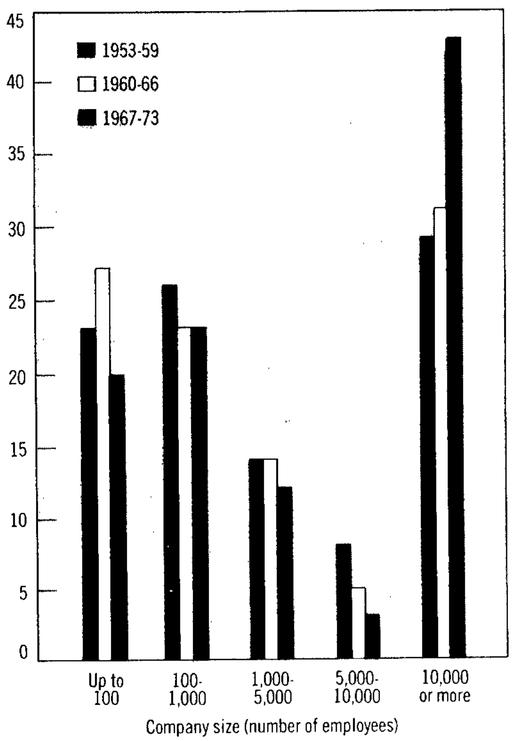
Industry	Illustrative innovations
Chemicals and allied products	freezing of foods by direct contact with liquid freon freezant; eponymous graphite filaments with extremely high strength per unit weight; desalination process for sea water.
Machinery	robot "hand" capable of humanoid manipulation of objects; optical scanning equipment to read characters on cards; a desk-top computer to fill the gap between conventional desk calculators and expensive full-sized computers.
Electrical equipment and communication	lasers; video tape; integrated circuits.
Aircraft and missiles	real-time computer systems allowing analysis and revision of stored information at a pace established by the user; a commercial passenger jet aircraft; jet air cargo carrier.
Professional and scientific instruments	copier using xerography on wide range of papers; holography via laser; fiber optics.
Petroleum refining and extraction	epoxy-resin/glass-fiber composite; secondary oil recovery by the use of carbon dioxide gas and water; process to recover hydrocarbon vapors at petroleum refineries.
Rubber products	reinforced-plastic refrigerated truck trailer; synthetic rubber; radiation curing of plastics.
Stone, clay, and glass products	a silicon carbide crystalline fiber; a ceramic refractory; precast concrete structural members for building construction.
Fabricated metal products	electrostatic-powder spray for adhesive and paint applications; steel scaffolding in standardized sections; stainless steel screens which pass light but are impermeable to liquids.
Motor vehicles and other transportation equipment	automobile seat belts; holographic measurement of designer's models to facilitate drafting; offshore mining vessel for collecting manganese nodules from the sea bed.
Food and kindred products	textured granular proteins for food; an aseptic canning process.
Textiles and apparel	resin treatment for shrink resistant wool; silicon rubber insulation; synthetic fiber rugs.
Lumber, wood products, and furniture	laminated wood structural members for building construction; a pressure-treated wood classified as noncombustible in certain fire insurance ratings.
Paper and allied products	water recycling system that recovers paper fibers for reuse and reduces fresh water requirements of paper mills; manufacture of newsprint from sugarcane (bagasse); cross-hatched, embossed paper for strong paper packaging.
Primary metals	oxygen steel converter process; permanent magnet alloys using rare earths; nickel extraction process for laterite and sulfide ores.
Nonmanufacturing industries	time-sharing computer systems; ocean going freighter built to carry cargo shipped in containers; adhesive temperature-monitoring labels.

SOURCE: Gellman Research Associates, *Indicators of International Trends in Technological Innovation*, 1976.

4-30

Distribution of major U. S. innovations by size of company, 1953-73

(Percent of the innovations in each time period)



REFERENCE: Appendix Table 4-18.

4-31. Estimated innovation rate, in major innovations per R&D dollar[1]

Time interval	Firm size (total number of employees) 1-1,000	1,000-10,000	10,000+
1953-59	100.0	29.5	3.9
1960-66	64.4	14.4	2.2
1967-73	35.1	9.0	2.0
1953-73 total	57.3	15.0	2.4

[1] Numbers are relative to the innovation rate for companies of 1 to 1,000 employees in the 1953-59 period; this rate is assigned the value 100.

SOURCE: Appendix Table 4-18; and *Research and Development in Industry, 1974*, National Science Foundation (NSF 76-322), p. 26.

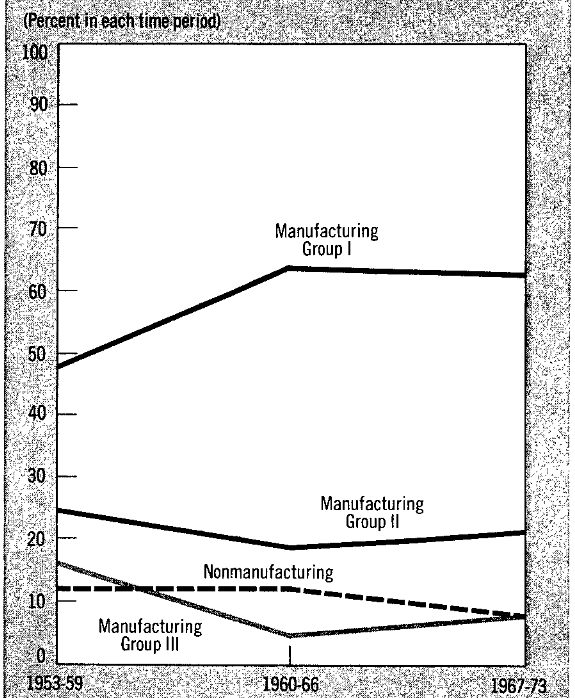
in the sample studied by the R&D expenditure of the entire size group in the middle year of the appropriate time interval. The results are shown in Table 4-31.

The numbers shown are proportional to the number of major innovations produced per R&D dollar, under the stated assumptions. One obvious trend is a drop in this quantity from one time period to the next, sometimes approaching a factor of two. Much of this can probably be attributed to inflation. The other trend, which is even stronger, is the drop in innovation rate as one moves from smaller to larger firms in a given time period. From the smallest to the middle-sized firms the drop is by a factor of three or four. Between the middle-sized and the largest firms the rate drops by a factor varying from five to eight. For the whole 1953-73 period, the smallest firms produced about 4 times as many major innovations per R&D dollar as the middle-sized firms and 24 times as many as the largest firms.

The limitations in the data underlying this table have been noted. It should also be repeated that an innovation is not the product of R&D alone, but also requires a tooling, manufacturing, and marketing effort which often involves a much greater expenditure than the R&D did. Hence R&D expenditures do not measure the total effort that industry puts into innovation. In addition, the table does not distinguish between more and less expensive major innovations. It is conceivable that larger firms have fewer major innovations per R&D dollar because they produce the more expensive ones. It may also be that larger firms tend to produce minor rather than major innovations, e.g., small improvements that reduce the cost of high-throughput manufacturing processes rather than completely novel products.

Innovation and industry group. It is plausible to suppose that, other things being equal, the industries that devote more of their resources to R&D will also be more innovative. This hypothesis was tested on the sample set of major innovations. The results are shown in Figure 4-32, in terms of the percent of innovations produced in each industry group in each of three time periods. As predicted, Manufacturing Group I produced the greatest number of innovations, 59 percent of the total, followed by

4-32
Distribution of major U. S. innovations by industry group, 1953-73



REFERENCE: Appendix Table 4-19.

Group II, with 21 percent. Group III and nonmanufacturing industries behaved similarly, producing 9 and 11 percent, respectively, of the total. The share attributed to each industry group changes little from one period to another. The most significant change is from the first to the second period, particularly for Group III.

These results can be compared with the total funds that these industry groups spent for R&D in roughly the same overall period, from 1958 to 1973.[20] Group I spent 78 percent of the total, while Group II spent 15 percent, Group III 4 percent, and nonmanufacturing industries 3 percent. Thus the group that spent the most for R&D produced the most innovations, but not in proportion to its dollar input. Equivalently, the groups that spent the least for R&D obtained the greatest number of major innovations per R&D dollar.

In the case of the manufacturing industries, it is also possible to compare the number of innovations with total net sales for each R&D intensity group. Group I had 40 percent of manufacturing industry net sales for these three groups in the period 1961 to 1973. Group II had 32 percent and Group III 27 percent.[21] Hence Group I had much more than its share of major innovations, by this measure, while Group II had less than its share and Group III much less.

Individual industries can also be compared with respect to their production of major innovations. This is done in Figure 4-33, which shows the percent of the total set of major innovations studied that were attributed to each of the manufacturing industries, with nonmanufacturing industries added for comparison. The four manufacturing industries showing the greatest innovative output—electrical equipment and communication, chemicals and allied products, machinery, and professional and scientific instruments—belong to R&D Intensity Group I. The fifth Group I industry—aircraft and missiles—produced fewer innovations. This may be because only those defense and space innovations that were introduced into the commercial market were included in the sample studied. On the other hand, the primary metals industry, which belongs to Intensity Group III, produced a relatively high number of innovations.

While Figure 4-33 indicates the distribution of major innovations according to industry, it does not allow for the fact that the various industries contain different numbers of companies, of different sizes, and also have different total R&D expenditures. An attempt to take these factors into account is made in Table 4-34. This table shows the number of major innovations for each industry, divided by the total net sales of that industry, or its total R&D expenditures, for as many years as possible in the 1953-73 interval.[22]

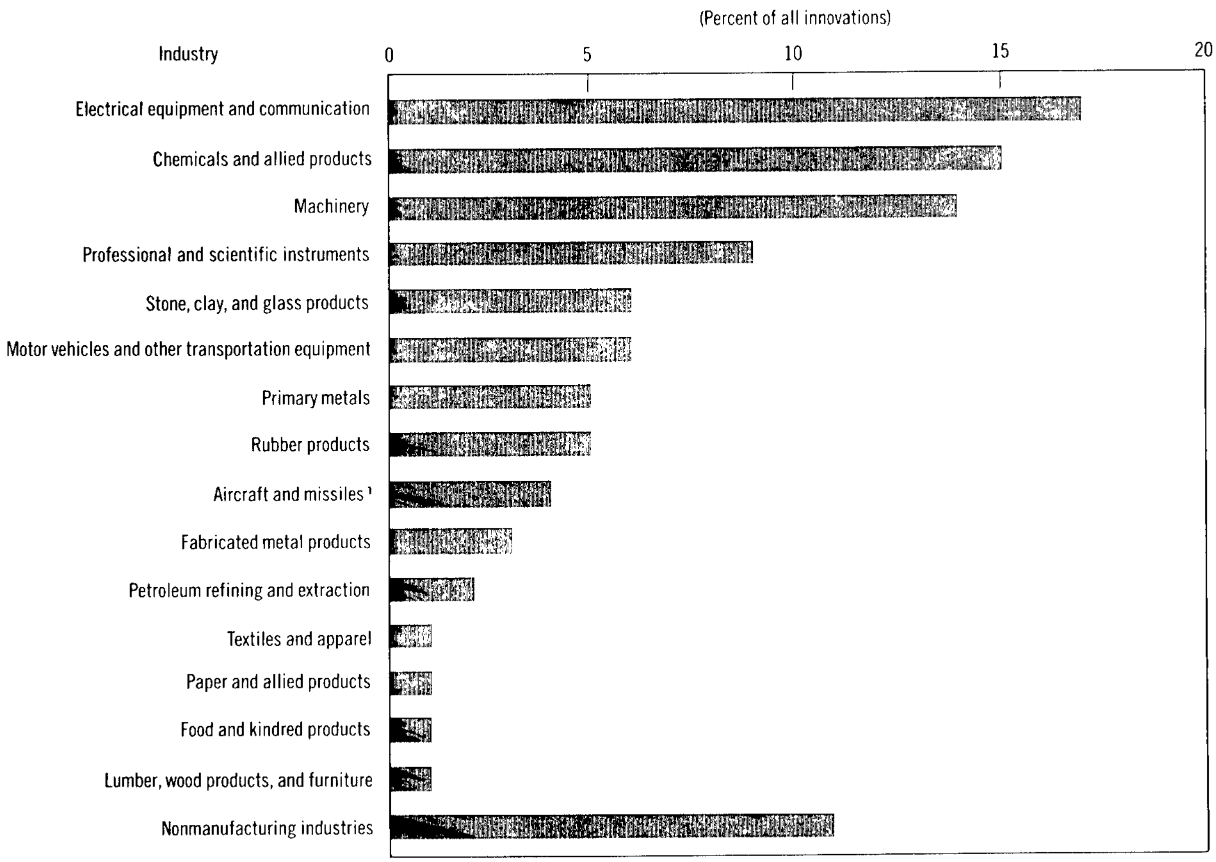
[20] *Research and Development in Industry, 1973*, National Science Foundation (NSF 75-315), p. 26 and *Research and Development in Industry, 1971*, National Science Foundation (NSF 73-305), p. 28.

[21] *Research and Development in Industry, 1974*, National Science Foundation (NSF 76-322), p. 54 and earlier volumes.

[22] Net sales data are available from 1961 onward, total R&D data from 1958 onward. Since Table 4-34 shows each industry in comparison with one industry chosen as a basis, the fact that these expenditure data do not go back to 1953 is partly compensated for.

4-33

Percent distribution of major U. S. innovations by industry, 1953-73



[1] Innovations in the defense and space areas are included only if they were introduced into the commercial market.

REFERENCE: Appendix Table 4-20.

In terms of net sales, the professional and scientific instruments industry and the stone, clay, and glass products industry were especially innovative. The most innovative industry, in terms of R&D expenditures, was the stone, clay, and glass products industry, followed by the wood products, textiles, and rubber industries. None of the five manufacturing industries with the most innovations per R&D dollar belong to R&D Intensity Group I. This is consistent with the observation made above that the less an industry group spent on R&D, the more innovations it obtained per R&D dollar.

Industries can be still more finely classified with the aid of the Standard Industrial Classification. This makes it possible to show the specific industrial areas in which major innovations occurred most frequently in the 1953-73 period, on the basis of the sample of innovations investigated in this study. The results are shown in Table 4-35 for three successive 7-year periods.

The prominence of electronics is evident in the last two periods. The chemical industry is prominent in the first period (drugs, industrial organic chemicals) and the second (plastics), while the motor vehicle industry, including tire manufacture, is important in the first and third periods.

4-34. Major innovations per net sales dollar and per R&D dollar, by industry, 1953-73[1]

Industry	Innovations per net sales dollar[2]	Innovations per R&D dollar[3]
Electrical equipment and communication	1.00	1.00
Chemicals and allied products	.99	2.11
Machinery	1.08	2.26
Professional and scientific instruments	2.59	3.75
Stone, clay, and glass products	1.83	9.74
Motor vehicles and other transportation equipment	.34	.88
Primary metals	.48	5.19
Rubber products	1.29	5.58
Aircraft and missiles[4]	.37	.15
Fabricated metal products	.60	3.78
Petroleum refining and extraction	.09	.86
Textiles and apparel	.33	5.88
Paper and allied products	.22	2.31
Food and kindred products	.04	.78
Lumber, wood products, and furniture	.37	6.08
Nonmanufacturing industries	NA	5.01

[1] Numbers shown are relative to the innovations per dollar for the electrical equipment and communications industry. This is the manufacturing industry with the most innovations, as seen in Figure 4-33.
[2] Net sales dollars are for 1961-73 only.
[3] Total R&D dollars are for 1958-73 only.
[4] Innovations in the defense and space areas are included only if they were introduced into the commercial market.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), pp. 26 and 54 and earlier volumes, and Gellman Research Associates, *op. cit.*

4-35. Narrow industry classes producing the greatest number of major innovations, for three time periods

1953-59

Drugs
Motor vehicles and equipment
Industrial organic chemicals
Tires and inner tubes

1960-66

Electronic components and accessories
Office and computing machines
Plastics materials and synthetics
Miscellaneous plastics products
Communication equipment
Research and development laboratories and other business services
Medical instruments and supplies

1967-73

Electronic components and accessories
Motor vehicles and equipment
Special industry machinery
Photographic equipment and supplies
Abrasives, asbestos, and other nonmetallic mineral products

SOURCE: Gellman Research Associates, Inc., *op. cit.*

Estimated radicalness of innovations. Innovations range from imitations of existing technologies to developments of radically new technologies and products. At one end of the spectrum, little new knowledge may be involved in an innovation, while at the other end, new and fundamental advances in knowledge and technique may have been required. In the present study, the distribution of major innovations along this spectrum was estimated by obtaining ratings of the radicalness of the innovations. These ratings were made by the innovating organizations themselves. Although inherently subjective, such ratings may provide some valid insights regarding trends in industrial innovation. Another limitation that may be noted is that the radicalness of innovations does not necessarily determine their economic or social significance. Innovations that represent only minor improvements or even imitations of existing technology may have greater economic returns or social consequences than more radical innovations.

The respondents provided ratings for 250 of the 310 U.S. major innovations, by assigning each to one of the following classifications: radical breakthrough, major technological shift, improvement, imitation, or no new technological knowledge required. The last two classifications, which describe the lowest degree of radicalness, together comprised only 8 percent of all the innovations and are combined in this discussion.

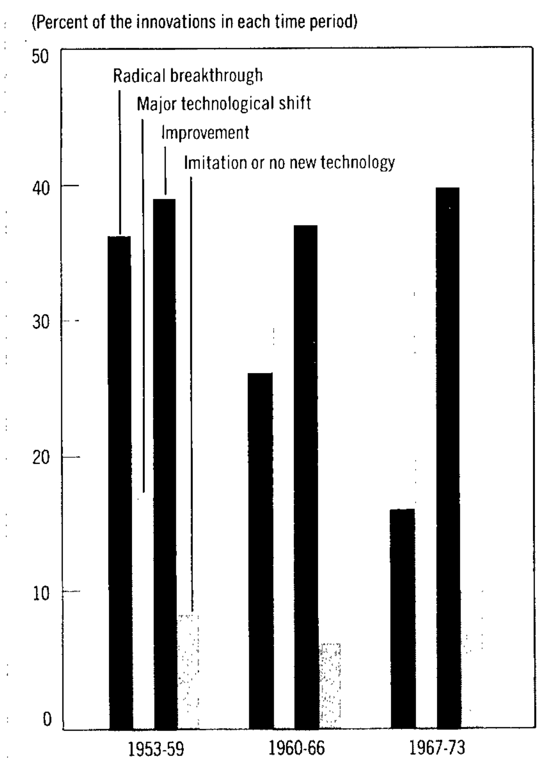
Figure 4-36 shows the distribution of innovations among the categories in each of the three 7-year intervals from 1953 to 1973. Over this period as a whole, major innovations involving improvement were the most frequently reported, amounting to 38 percent of the total. This compares with 28 percent reported as major technological shifts and 26 percent as radical

breakthroughs. The most significant change in this distribution in this overall period was a steady drop in the reported radical breakthroughs from 36 percent of the innovations in 1953-59 to 16 percent of those in 1967-73. This was almost balanced by an increase in the proportion of innovations ranked as major technological shifts from 17 percent of the 1953-59 innovations to 35 percent of those in 1967-73.

Figure 4-37 shows the radicalness ratings according to industry group as well as time interval. The overall decrease in major innovations called radical breakthroughs is seen to be due primarily to a reduction in the number of such innovations from Manufacturing Group I, which is the most R&D-intensive group. In 1953-59 and 1960-66, 19 percent of all innovations were radical breakthroughs from

4-36

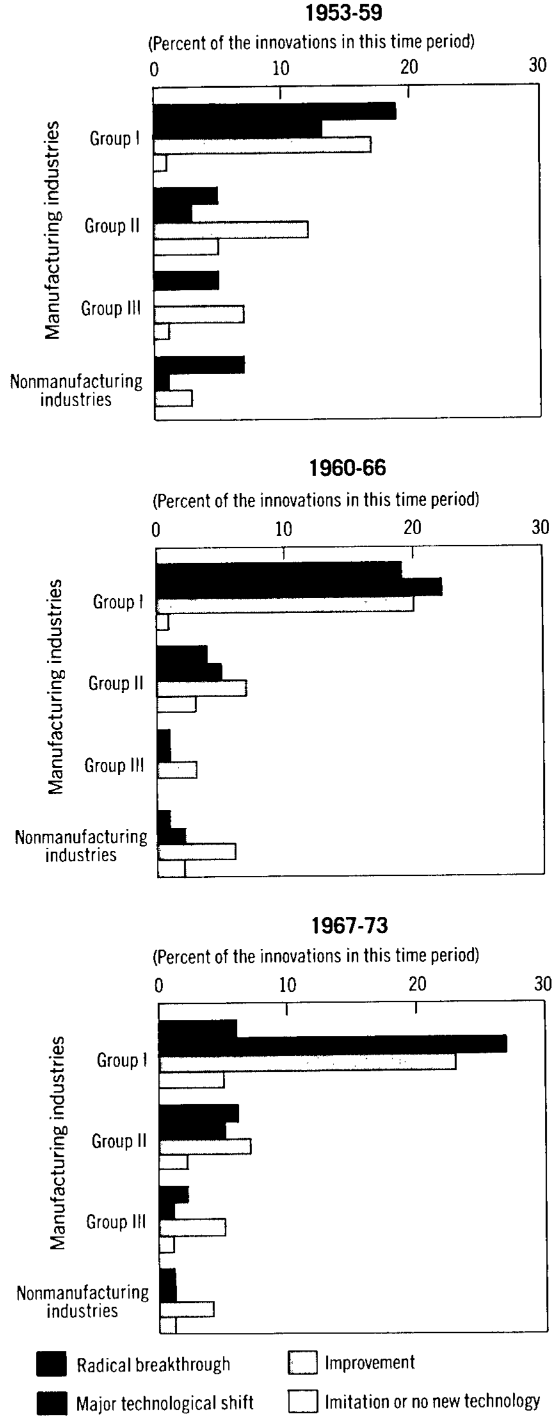
Estimated radicalness of major U. S. innovations, 1953-73



REFERENCE: Appendix Table 4-21.

4-37

Estimated radicalness of major U. S. innovations by industry group, 1953-73



REFERENCE: Appendix Table 4-22.

Group I. This figure dropped to 6 percent of all the innovations marketed in 1967-73. The percentage of major technological shifts from Group I industries increased to offset this decline in major breakthroughs. Other industry groups also showed declines in their percentages of radical breakthroughs from their 1953-59 level, but to a greater extent their innovations were only reported as improvements.

Over the whole 1953-73 period, the Group I manufacturing industries had an especially high number of major technological shifts (53, as Appendix Table 4-22 shows) and an especially low number of innovations that were only imitations. Group II had a higher number of imitations (9), than other groups, while Group III had a lower number of major technological shifts (2). Otherwise, the distribution of the degree of radicalness of innovations over industry groups was rather uniform.

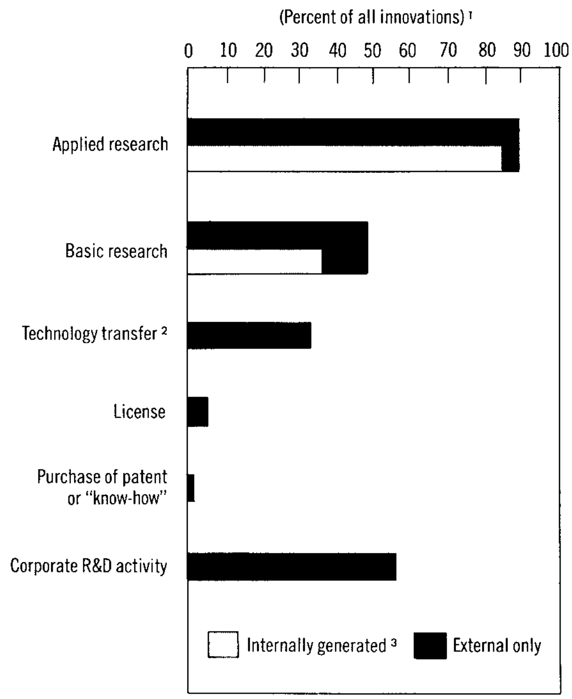
Sources of technology underlying innovations. The technology underlying an innovation may be acquired in a variety of ways. These include basic research, applied research, licensing, merger or acquisition of a going concern, the transfer of technology from an existing product of the innovating enterprise, and the outright purchase of a patent or know-how. The basic or applied research may have been generated within the innovating company, or it may have been done on the outside. Within the company, an official centralized R&D organization may have done the research, or it may have been done elsewhere in the company, e.g., in a manufacturing division. Various combinations of these means may be involved in the case of a single innovation. For example, the underlying technology for the high-speed phototypesetting machine was acquired through a combination of internally generated basic and applied research, along with the transfer of technology from one of the firm's existing product lines.

The sources of the technology underlying the major innovations in this study are shown in Figure 4-38. These data were supplied by the innovating firms, and cover about 250 innovations. For each one, the firm could indicate any number of sources from the list provided (shown in Appendix Table 4-23) and all such indications were counted equally.

The dependence of innovation on research—applied and basic—is evident from the figure.

4-38

Distribution of major U. S. innovations by source of technology, 1953-73



[1] Multiple responses were accepted.
[2] From an existing product of the same company.
[3] Wholly or partly internally generated.
REFERENCE: Appendix Table 4-23.

Applied research contributed to nearly 90 percent of the major innovations, and basic research to nearly 50 percent. In both cases, almost all the research reported was performed within the innovating company; 85 percent of all major innovations involved internally generated applied research, and 36 percent internally generated basic research. (These numbers include the innovations for which the research was both internal and external, but such innovations amount to only 4 percent of all the cases in which internally generated research was reported.) The reports of internally generated research are more reliable than those of external research, since the respondents could not be expected to know as much about the latter.

Corporate research centers contributed to the underlying technology of 56 percent of the innovations. Since a greater percentage of

innovations than this benefited from internally generated applied research, it is evident that much of this research was done elsewhere in the innovating company. Some of the internal basic research may also have been done outside the research centers. Aside from research, the only significant source of technology was the transfer of technology from an existing product of the same company; this occurred in the case of 33 percent of the innovations.

As was noted, the responding firms were not necessarily aware of the extent of the research underlying their innovations that had been performed outside the company. They were very possibly not aware of the basic research contributing to their own internal research, which might have been performed at universities or elsewhere outside industry. In addition, the research underlying transferred technology was not considered. Hence the numbers reported here should be considered lower limits for the actual contributions of research to innovation.

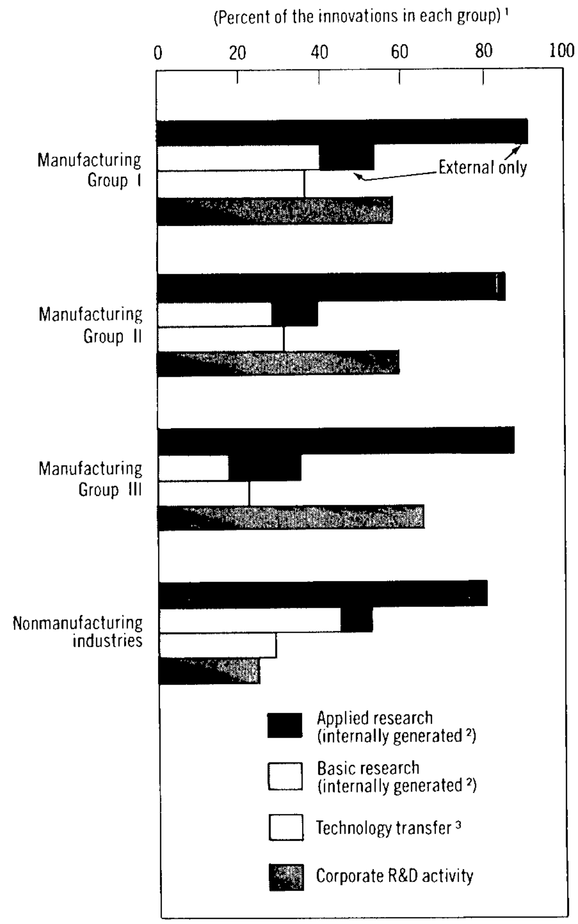
The sources of technology can also be studied by dividing the innovations according to the industry group to which the innovating company belongs (Figure 4-39). All industry groups relied on applied research for at least 80 percent of their major innovations, and contributed their own applied research to at least 74 percent. The higher R&D-intensity groups showed more dependence on both basic research and internal technology transfer. Manufacturing Group II industries depended more than the other manufacturing groups on outside research, though they also showed a marginally greater reliance on their own corporate research centers. Nonmanufacturing industries relied on basic research for a large portion of their innovations, but reported relatively little involvement on the part of their research centers. This would imply that they performed a great deal of both basic and applied research outside such centers.

It is also possible to show the sources of technology for the innovations according to the degrees of radicalness that those innovations were assigned, as in Figure 4-40. As would be expected, the major innovations labeled imitation or no new technological knowledge required relied on relatively few technology sources of any kind. This part of the figure is based on only a small sample. Otherwise, it is found that all radicalness classes depended heavily on applied research. The more radical innovations were based more frequently on basic research, but less frequently on internal technology transfer or R&D performed at the corporate R&D center.

On Figure 4-41, the percent of the major innovations that were assisted with public funds is shown for each R&D-intensity class of manufacturing industries and also for nonmanufacturing industries. Public funds include government grants and contracts. Group I, the most R&D-intensive group of manufacturing

4-39

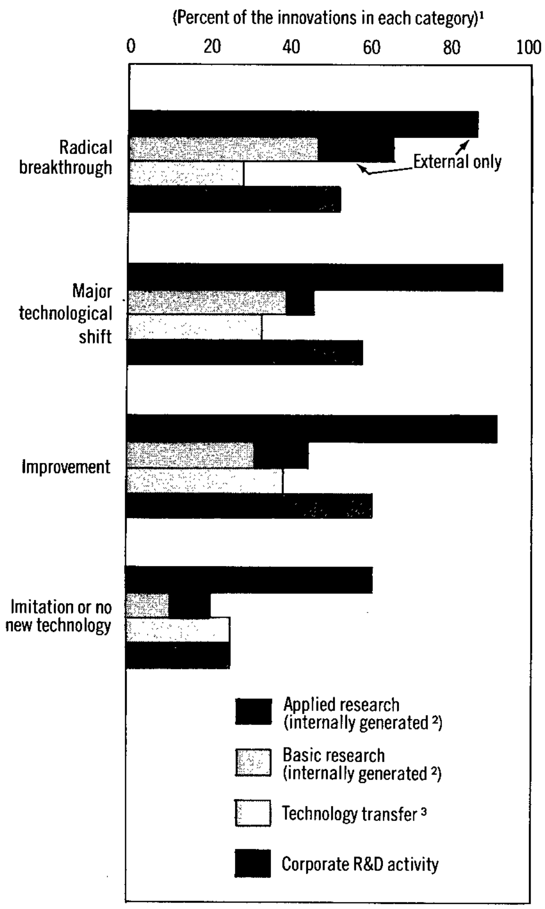
Distribution of major U. S. innovations in each industry group by source of technology, 1953-73



[1] Multiple responses were accepted
[2] Wholly or partly internally generated
[3] From an existing product of the same company.
REFERENCE: Appendix Table 4-24

4-40

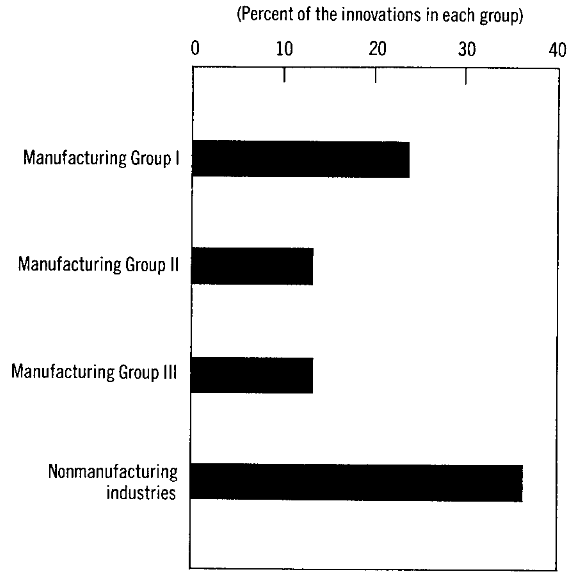
Distribution of major U. S. innovations in each radicalness category by source of technology, 1953-73



[1] Multiple responses were accepted.
[2] Wholly or partly internally generated.
[3] From an existing product of the same company.
REFERENCE: Appendix Table 4-25.

4-41

Major U. S. innovations assisted by public grants or contracts, by industry group, 1953-73



REFERENCE: Appendix Table 4-26.

industries, reported a much higher frequency of public support than the other two groups of manufacturing industries. Nonmanufacturing industries reported an especially high frequency of public funding, but since fewer innovations are involved in this case the significance of this result is less certain.

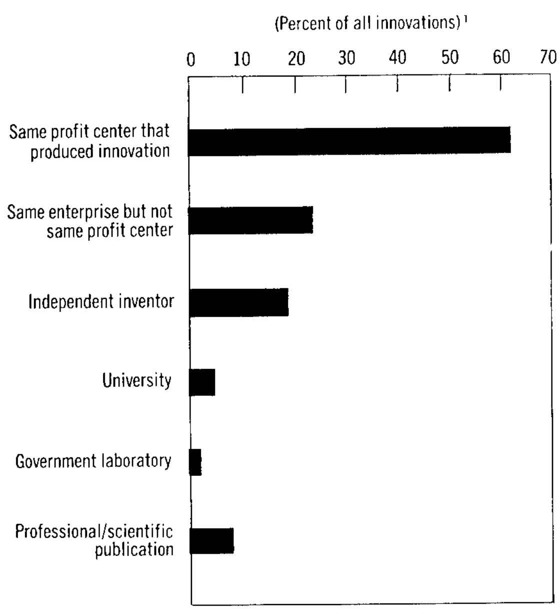
The innovating companies were also asked what the sources were of the invention or conception that underlay their innovation. As Figure 4-42 indicates, the great majority reported that it was the same profit center that produced the innovation. The next most frequent answer was another part of the same enterprise. Many also cited an independent inventor as the source.

SOCIAL AND ECONOMIC RETURNS FROM R&D AND INNOVATION

The social and economic effects of innovation in general, and of R&D in particular, are not yet understood well enough to make possible the presentation of quantitative indicators of these effects. A number of studies have been conducted, but their frequent differences of method, range, and basic conceptualization make it difficult to pull together a reliable general picture. In place of definite indicators, and in anticipation of future efforts in this area, this section will present some tentative conclusions that summarize many of the investigations that have been conducted.

4-42

Distribution of major U. S. innovations by source of invention or conception, 1953-73



[1] Multiple responses were accepted.
REFERENCE: Appendix Table 4-27.

The contribution of R&D to economic growth and productivity is "positive, significant, and high" (1).[23] This contribution occurs through technological innovation in the form of new and improved production processes, products, and services. These may expand economic output, increase productivity, or reduce unit costs. Such innovation is an important—perhaps the most important—factor in the economic growth of the United States in this century (2-4). On the other hand, it is widely recognized that there are costs associated with technological change, including dollar costs. For example, pollution due to technological change causes expenses both to industry and consumers. Such costs must be deducted from the economic benefits attributed to innovation.

Investment in R&D and innovation yields a rate of return as high as—and often higher than—the return from other investments. This applies to investments for specific innovations by both the public and private sectors, and to R&D investments by individual industries. Rates of return from specific innovations are estimated, conservatively, to average between 10 and 50 percent per year (5-10), while returns to innovating industries, in the form of productivity growth, range from 30 to 50 percent (11-19).

The benefits to industries which purchase new or improved products from innovating firms may equal or exceed the direct returns to the innovating firms themselves. These benefits occur particularly in the form of reduced prices or costs per unit of output to the industries that purchase or use the innovations. The rates of return to these industries are estimated to range from 20 to 80 percent per year (20-22).

Industry may underinvest in R&D and innovation, in terms of their probable ultimate benefits to the firm and to society (23-25). There are several disincentives to a firm's investing as much as the average returns from R&D and innovation would warrant. There may be uncertainty and risk involved in specific innovation efforts, as well as a long delay before returns can be expected. The scale of investment required may be too great for that firm. Even though the potential benefit to society may exceed the cost of innovation, the firm may not be able to translate enough of those benefits into its *own* profits to justify the necessary investment. "This is particularly true of basic research, where the output frequently occurs. . .not as a marketable product but rather as an advance in basic knowledge that can subsequently be used in applied research and development by a wide and often unforeseeable range of firms" (25). Additional hindrances may take the form of inadequate property-rights protection for new ideas and technologies, the costs of establishing and enforcing such rights, or the difficulties and costs of technology transfer by licensing and patent pooling (5, 26). However, overinvestment is also possible; better models are needed before it is possible to say that underinvestment is the rule.

Standard indices of economic performance, such as Gross National Product or output per man-hour, reflect only part of the contribution which R&D and innovation make to the economy and society (27). Technological innovation often results in new products and services that satisfy needs and wants not satisfied previously. The value of such innovations to the consumer may far exceed the price he pays for the product or service, but only the latter is counted in standard economic measures. Similarly, the

[23] These numbers refer to the references provided at the end of this chapter.

effects of quantitative improvements in existing products and services, resulting from innovation, may not be represented adequately by the common economic indices. In fact, innovations of this kind may contribute less to economic growth as commonly measured than was contributed by the unimproved products or services. Standard economic indicators sometimes even misrepresent the costs of technological innovation to society as benefits. Expenses that the public incurs in alleviating certain kinds of pollution, for example, are counted as part of the GNP. Thus they superficially appear to be gains in the public's standard of living. Again, in present economic accounting, goods and services provided to the public sector through nonmarket channels are valued at cost, rather than at market prices. Thus, benefits from R&D and innovation in areas such as education and national defense may be underestimated by a considerable margin in conventional economic indices. These observations suggest that conventional economic measures fail to capture the full impact of technological innovation on the economy and society. These and other defects of method would seem to result in a general underestimation of the contributions and returns to society from R&D and innovation (28). However, some studies have attempted to improve on the standard measures. These studies take into account not only the dollars saved by those who buy industrial products at lower prices, but also any attendant increase in consumer welfare from price reductions, as well as any social costs that innovations produce (5, 6, 21, 29-36).

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Chapter 5

Science and Engineering Personnel

Science and Engineering Personnel

INDICATOR HIGHLIGHTS

- Employment of scientists and engineers in 1974 is estimated at over 1.7 million, about the same number as in 1970; engineers represented two-thirds of this total.
- More of the Nation's scientists and engineers were employed in industry than in any other R&D-performing sector—about one million in 1974—and over 80 percent of this group were engineers.
- The Federal Government supported less than 25 percent of all industrial scientists and engineers in 1974, down from nearly 30 percent in 1972; industry's life and environmental scientists had the lowest average level of Federal support, at about 5 percent, compared to the highest support (26 percent) for engineers.
- Universities and colleges employed about 289,000 scientists and engineers in 1976, about 8,500 or 3 percent more than the number employed in 1975; increases in the number of psychologists and social scientists accounted for 58 percent of this change.
- The 160,000 scientists and engineers employed by the Federal Government represented about one of every ten scientists and engineers in 1974. Over the 1964-74 period, employment of scientists and engineers in the Federal Government increased by almost 12 percent, while the employment of scientists and engineers throughout the economy rose by almost 25 percent.
- In 1975, approximately 531,000 scientists and engineers (on a full-time-equivalent basis) were engaged in R&D, 9,000 more than the number in 1973, but almost 28,000 fewer than the peak employment level reached in 1969.
- About one-third of all scientists and engineers were engaged in R&D activities in 1974. Of these, 68 percent were employed in industry, 13 percent in universities, and 12 percent in the Federal Government.
- The number of R&D scientists and engineers in industry increased each year from 1972 through 1975, when the total reached almost 360,000. However, the full-time-equivalent number in 1975 was still nearly 7 percent less than the peak employment reached in 1969, a decline which occurred primarily in the aircraft and missiles, and the electrical equipment communication industries.
- Academic R&D was conducted by 72,400 full-time-equivalent scientists and engineers in 1976, most of which was research, with very little emphasis on development. Of all the doctoral faculty involved in R&D, the proportion of young science and engineering investigators decreased from 44 percent in 1968 to 30 percent in 1974.
- In 1975, about 84 percent of all full-time science and engineering doctorate faculty were spending at least 20 percent of their time in research.
- The number of scientists and engineers with doctorate degrees reached almost 280,000 in 1975, up about 33,000 (13 percent) from 1973. During this 2-year period, the relative increase in the number of women doctorate-holders in science and engineering exceeded that of men.
- In 1975, educational institutions provided the largest source of employment for doctoral scientists and engineers, accounting for about 58 percent of the number employed, about the same proportion as in 1973. About 25 percent of the doctoral scientists and engineers were employed in business and industry in 1975.
- In 1975, 43 percent of the employed doctoral scientists and engineers reported the performance or management of R&D as their primary work activity, almost unchanged since 1973.

- The proportion of young doctoral faculty in doctoral level science and engineering departments declined from 43 percent in 1968 to 27 percent in 1975; over 70 percent of doctoral faculty in all fields had tenure in 1974.
- Women made up 6 percent of all persons employed in science and engineering occupations in 1974, although 9 percent of the total number (employed and unemployed) were women and about 50 percent of all professional and technical workers were women. Those employed were more highly represented among psychologists, computer scientists, and mathematicians than other fields. In the academic sector, women represented 15 percent of all scientists and engineers employed full-time in 1974.
- About 4 percent of all scientists and engineers in 1974 were members of racial minority groups. Asians accounted for 1.8 percent, Blacks about 1.5 percent, and other minority groups the remainder.
- Between 1972 and 1975, the proportion of National Merit Scholars choosing science as a major declined from 61 to 54 percent, while over the same period the proportion of those planning to major in engineering increased from 9 to 17 percent.
- In 1975, the annual awards of bachelor's and first-professional degrees in all fields combined, and specifically in the sciences and engineering, declined for the first time since 1955. However, as a fraction of these degrees awarded in all fields, those in science and engineering have remained essentially constant at nearly 30 percent since 1960. This nearly stable share is the result of a rapid growth in the number of social science degrees, combined with much more limited growth in physical sciences and engineering.
- Annual awards of master's level degrees in all fields continued to increase through 1975, but those in science and engineering peaked in 1973. Science and engineering accounted for 30 percent of all master's degrees awarded in 1965, but only 18 percent in 1975, with the greatest proportional declines occurring in engineering and the physical sciences.
- In 1976, the number of doctoral degrees awarded in the sciences and engineering had dropped to the 1970-71 level. As a fraction of all doctoral degrees, science and engineering degrees declined from 64 percent in 1965 to 54 percent in 1975, largely resulting from reduction in the physical sciences.

Scientific and engineering manpower is of great importance because these people are one of the key factors in the status and progress of science and technology. The persons who make up this manpower base conduct basic research to advance the understanding of nature, perform applied research and development in a variety of areas such as health, defense, and energy, and instruct and train the Nation's future scientists and engineers.

Thus, science and engineering manpower is a necessary component of a society as advanced technologically as the United States. Scientists and engineers are essential to the operation of a high technology economy. At least as important, however, are the scientific advances made by scientists and engineers which permit the Nation to remain at the forefront of international technological development.

The information about the Nation's scientists and engineers that this chapter presents is incomplete. Measures of the quality of their work, the extent of their "under-utilization," and the increasingly important concerns of productivity and output are not available. Also, little is known about motivational factors which lead students to enter science and engineering, or which influence those already in these fields to move from one type of employment to another. The present lack of such indicators, it is hoped, will be remedied in the future as the need for such information is more widely recognized and the appropriate studies are initiated.

Information on the specific activities of scientists and engineers, especially those in the academic sector, is limited by the current difficulty of obtaining data by field on major activities with joint outcomes, such as R&D and

teaching.[1] However, the number of scientists and engineers "primarily involved" in an activity provides a useful but relatively crude measure of this factor.

CHARACTERISTICS AND UTILIZATION OF SCIENCE AND ENGINEERING PERSONNEL

Employment of scientists and engineers

In the past quarter century, the levels of scientist and engineer employment have gone through a number of phases. For the most part, these shifts have not corresponded to total national economic activity, but to changes in only a few sectors of the economy.

Three distinct periods of scientist and engineer employment characterize the interval between 1950 and 1974. The first extended from 1950 to 1963. In these years there was a rapid growth of jobs for natural scientists, and especially for engineers, in response to increases in defense-related activities and the space program. Over this period, employment of scientists and engineers grew more rapidly than overall economic activity as measured by the Gross National Product and total nonfarm employment (Figure 5-1). The 1960's saw a relatively rapid increase in the employment of scientists as college enrollments and research programs increased. In the 1963-70 period, engineering employment changed more slowly. The rate of growth in the number of jobs in science and engineering was less than the growth in total nonfarm employment and overall economic activity. The comparatively slow growth in engineering employment reflected a number of factors, including cutbacks in defense programs and reduced space exploration activities.

From 1970 to 1974, employment of scientists and engineers increased at a slower rate than overall economic activity, reflecting slow growth (or reductions) in college enrollment, R&D expenditures, and defense activities—especially in aircraft and related products. Employment of scientists and engineers combined increased at an average annual rate of 0.7 percent in the period (0.3 percent for engineers and 1.4 percent for scientists). This overall rate, however, concealed a decline of 20,000 in engineering employment between 1970 and 1972.[2]

The full-time-equivalent number of scientists and engineers performing R&D is an important indicator of the level of scientific activity, along with the extent of R&D funding. Relative trends of employment in the various economic sectors and industries which employ these workers reveal the extent of R&D activity in these sectors and industries, and provides some insight into changes in the thrust of R&D activities.

In the 1950's and 1960's about half of the Nation's R&D expenditures were financed by defense and space research programs, and changes in total R&D expenditures reflected the fluctuations in these programs. By 1976, however, defense and space R&D represented only little more than one-third of total R&D expenditures, down from two-fifths in 1972.[3] As the proportion of R&D expenditures for defense and space has declined, the shares accounted for by such areas as health, the environment, and energy resources have increased.

Associated with these patterns and changes of R&D financing were factors relating to the changing industrial and occupational distribution of scientists and engineers since 1950. Two industry groups make up the bulk of defense/space-related R&D and production: the aircraft and missiles firms and the electrical and communications equipment manufacturers. In the early 1950's, before the space program began, scientists and engineers in these two defense/space industry groups accounted for about 12 percent of the total number of scientists and engineers. Near the peak of the space program in 1968, and at a time of high defense spending, these two industry groups employed 21 percent of scientists and engineers. By comparison they employed 5 percent of all private sector nonagricultural employees in 1950 and 7 percent in 1968. In 1974, these

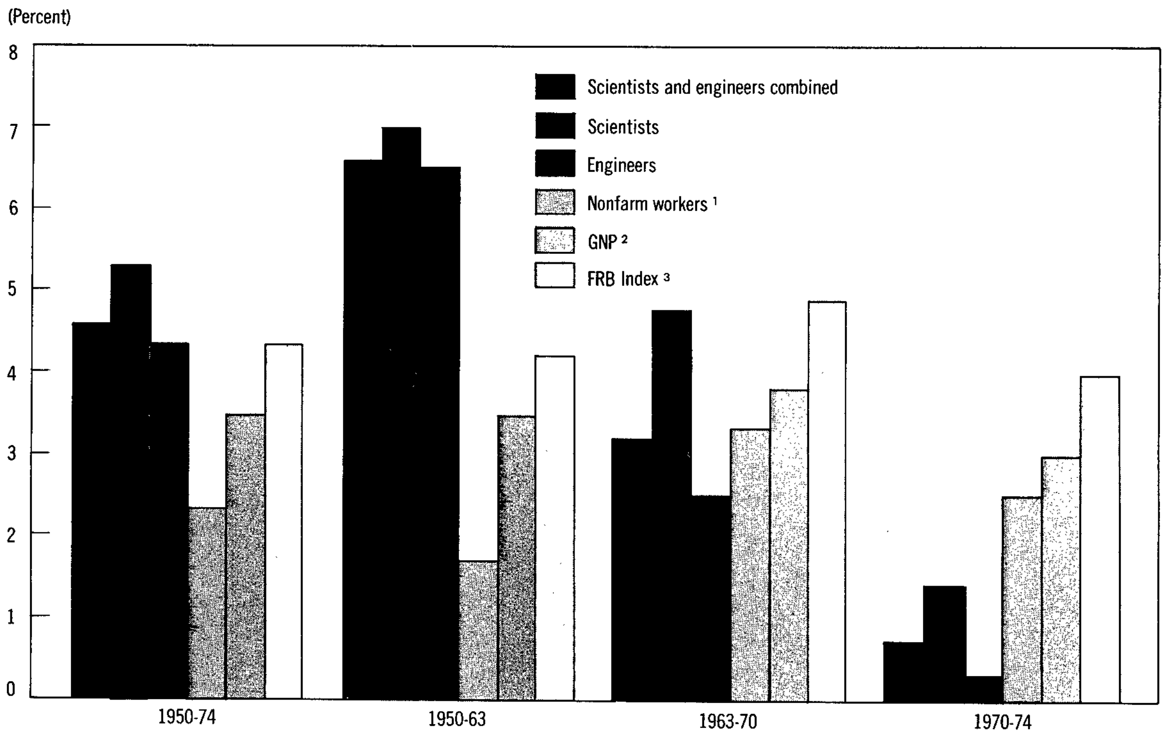
[1] The NSF is testing the feasibility of collecting this information from personnel records at higher education institutions.

[2] Science and engineering employment data are from the Bureau of Labor Statistics, Department of Labor, *Employment of Scientists and Engineers, 1950-1970*, 1973 (Bulletin 1781) and unpublished estimates of the B.L.S. for 1974. Other indicators are from *Economic Report of the President, Council of Economic Advisors*, 1976, pp. 172, 202, and 208.

[3] *National Patterns of R&D Resources, 1953-1976*, National Science Foundation (NSF 76-310), p. 32.

5-1

Annual average percent changes in science and engineering employment compared to other economic and manpower variables, 1950-74



[1] Nonfarm wage and salary workers.
[2] Gross National Product (constant 1972 dollars).
[3] Federal Reserve Board Index of Industrial Production.
REFERENCE: Appendix Table 5-1.

industries employed only 17 percent of all scientists and engineers and 6 percent of all private nonagricultural employees.[4]

The occupational composition within the scientific and engineering community has also been influenced by the activities generated by the Federal Government and its defense/space priorities. From the early fifties to the mid-sixties, as shown in Table 5-2, engineers represented more than 70 percent of the combined science and engineering work force.[5] By 1974 their share had fallen slightly to 68 percent, while the share of physical scientists remained between 15 and 16 percent through the entire period, and life scientists' share grew from 8 percent to 12 percent over these 24 years. These changes occurred as defense/space-related research declined in its relative importance and as other programs, such as health and environmental research, emerged. The "mix" between the scientist and engineer work force, however, has shown little change since 1970.

[4] *Employment of Scientists and Engineers, 1950-1970,* 1973 (Bulletin 1781); *Employment and Earnings, U.S., 1909-72,* 1975 (Bulletin 1312-9); and *Employment and Earnings,* March 1975. All of these reports were prepared by the Bureau of Labor Statistics, Department of Labor.

[5] Data for the period 1950-70 are from *Employment of Scientists and Engineers, 1950-70,* Bureau of Labor Statistics, Department of Labor, p. 11. The 1974 numbers are unpublished estimates from the Bureau of Labor Statistics.

5-2. Occupational distribution of employed natural scientists[1] and engineers by field, 1950-74

Field	1950	1960	1970	1974 (est.)
All fields Number (in thousands)	557	1,104	1,595	1,634
All fields Percent	100	100	100	100
Engineers	73	72	69	68
Physical scientists	16	16	16	15
Life scientists	8	9	11	12
Mathematicians[2]	3	3	4	5

[1] These data on natural scientists do not include social scientists or psychologists.
[2] The Bureau of Labor Statistics estimates that about one-half of the mathematicians in the 1970 and 1974 data could be classified into nonscientific occupations (such technicians as systems analysts, computer programmers, etc.), due to possible reporting errors by private industry in these years.

In the fifties and sixties the year-to-year growth in defense and space program expenditures had considerable impact upon the utilization of scientists and engineers, especially those performing R&D. In the seventies, however, changes in defense and space funding have had less effect on scientist and engineer employment. Industries have become less dependent upon defense/space financing, more self-sufficient, and more involved in other programs.[6]

In 1974 an estimated 1.6 million natural scientists and engineers were employed throughout the economy, representing an increase of about 50,000 over the 1972 employment level and about 37,000 more than the previous peak employment level of 1970. In addition, an estimated 160,000 social scientists and psychologists were employed in 1974.

Industrial employment of scientists and engineers

Over one million scientists and engineers were employed in the industrial sector in 1975, continuing industry's role as the largest employer of scientists and engineers.[7] Employment, however, has fluctuated over the 1970-75 period.[8] Layoffs of scientific and technical personnel in industry in 1971-72 were followed by increases in employment of these workers, reflecting the general upturn of the economy which began in late 1973 and early 1974.

Engineers significantly outnumbered scientists in the industrial sector, accounting for almost 75 percent of the total employment of scientists and engineers in that sector in 1975. Physical scientists (including environmental scientists) accounted for 9 percent of the total and computer scientists, 12 percent.

Almost 30 percent of the industrial scientists and engineers had R&D and its management as their primary activity in 1974 (see Table 5-3). There were some differences, however, between the primary activity patterns of scientists and of engineers. A greater proportion of industrial scientists was primarily engaged in R&D and the management of R&D than was the case for engineers (37 percent compared with 26 percent). For engineers, the next most common activity was management of non-R&D activities, while for scientists it was the area of computer applications.

Only 23 percent of all scientists and engineers in industry received Federal Government support in 1974, compared to 28 percent in 1972.[9] This decrease was evident in most fields. Relative levels of support, however, varied widely among the different fields. In 1974, 26

[6] *National Patterns of R&D Resources, 1953-76,* National Science Foundation (NSF 76-310), pp. 11 and 32.
[7] *U.S. Scientists and Engineers: 1974,* National Science Foundation (NSF 76-329), p. 26.
[8] National Science Foundation, unpublished data.

[9] The data in this paragraph refer to the 1974 status of those who were considered scientists and engineers in the 1970 Federal Census.

5-3. Percent distribution of the 1970 science and engineering labor force employed in industry in 1974, by primary work activity

Primary work activity	Total	Scientists	Engineers
Total	100	100	100
R&D and R&D management	29	37	26
Management of non-R&D activities	19	15	20
Production and inspection	16	13	17
Design	14	1	18
Computer applications	6	19	2
Other activities	16	15	17

SOURCE: National Science Foundation, unpublished data.

percent of the engineers and 22 percent of the mathematical scientists received Federal support; the same was true for only 10 percent of the physical scientists and approximately 5 percent of the life and environmental scientists in business and industry. Most life and environmental scientists who receive Federal support are employed by universities and Government, rather than by industry.[10]

Academic employment of scientists and engineers

Between 1975 and 1976, employment of scientists and engineers in universities and colleges increased 8,500, or 3 percent, reaching 289,000.[11] Approximately 58 percent of the rise was in the employment of social scientists and psychologists. However, these two fields together represented only 26 percent of all scientists and engineers employed in universities and colleges in 1976.

The approximately 289,000 full-time and part-time scientists and engineers in 1976 represent a 62 percent expansion over the almost 179,000 employed in 1965. Most of the growth occurred between 1965 and 1971, with increases in all scientific disciplines. The average annual rate of growth in academic employment of scientists and engineers between 1971 and 1976 was only 2.3 percent, compared with 6.3 percent during 1965 through 1971. The greatest growth occurred in the employment of life scientists and social scientists, which together accounted for approximately 54 percent of the overall increase between 1965 and 1976 (Figure 5-4).

The attainment of the doctoral degree in the sciences and engineering became increasingly important for employment at colleges and universities during the early 1970's, as employment opportunities slackened in this sector. The number of scientists and engineers with academic or health profession doctorates increased about 17 percent between 1971 and 1976, compared with only a 5 percent increase in the employment of persons with less than the doctorate (Figure 5-5). By 1976, 65 percent of all academic scientists and engineers had doctoral degrees, about the same proportion as during 1973 to 1975, but up from 60 percent in 1965.

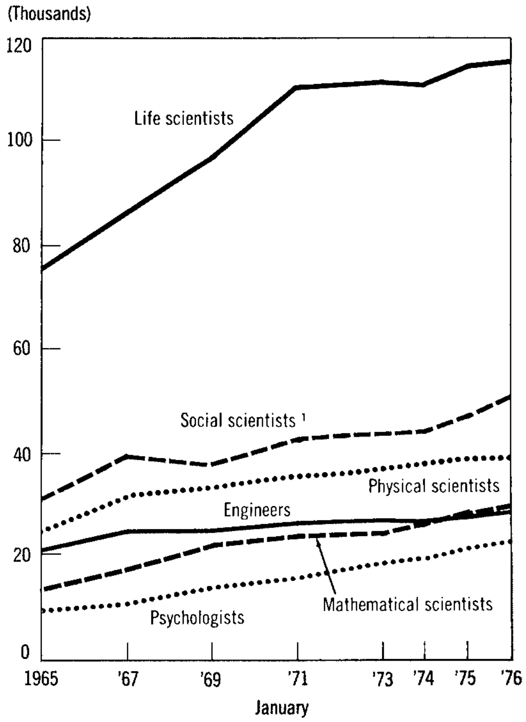
Among academic scientists and engineers, a relatively greater proportion of the total has been primarily involved in teaching, with a correspondingly smaller fraction primarily working in R&D (Appendix Table 5-4). In 1976, 18 percent were primarily engaged in R&D, compared with 22 percent in 1965. The rapid growth of 2-year academic institutions, where teaching is the primary activity of almost all the faculty, is responsible for part of this shift. Other academic institutions, including the large research universities, also experienced a movement toward more teaching by scientists and engineers. Four-year institutions reported an average annual percentage rise of 5.6 percent in the number of scientists and engineers working primarily as teachers over the 1965-76 period, with only a 2.2 percent average annual growth of those working primarily in R&D (Figure 5-6). In 1976, 77 percent of all scientists and engineers in universities and colleges were primarily engaged

[10] *Characteristics of the National Sample of Scientists and Engineers, 1974: Part 2, Employment,* National Science Foundation (NSF 76-323), pp. 118 and 122.

[11] *Manpower Resources for Scientific Activities at Universities and Colleges, January 1976,* Detailed Statistical Tables, National Science Foundation (NSF 76-321), p. 1.

5-4

Scientists and engineers employed in universities and colleges by field of employment, 1965-76



[1] Excluding historians.
REFERENCE: Appendix Table 5-2.

in teaching, as in 1975, but up from 68 percent in 1965.

The number of academic scientists and engineers working primarily in R&D has been growing while Federal R&D support to universities and colleges has been declining. Academic expenditures for R&D from all sources declined 6 percent from 1968 to 1975 in constant dollars.[12] The financial status of academic R&D might have been worse except for substantial increases in R&D support by the institutions themselves and by State and local governments.

[12] *Expenditures for Scientific Activities at Universities and Colleges, Fiscal Year 1976*, National Science Foundation (NSF 76-316), based on p. 3.

The age distribution of all faculty scientists and engineers is not known, but data do exist for doctoral faculty at 4-year colleges and universities. Science and engineering fields vary considerably with respect to age distribution (see Table 5-7). In 1975, for example, academic mathematical scientists and computer specialists had median ages of 38.6 and 38.9 years respectively, compared to 41.3 for all doctoral science and engineering faculty and in contrast to 44.9 for agricultural scientists.

Another indicator of these inter-field differences in age is included in Table 5-7: the proportion which is under 40 years of age. By this measure, agricultural science faculty are by far the oldest group, with only 34 percent under 40 compared to an average for all fields of 46 percent, and the relatively high percentages below 40 years of age for mathematical scientists and computer specialists of 57 and 55 percent, respectively.

No appreciable change is seen from 1973 to 1975 in the median ages or the proportion under 40 of doctoral science and engineering faculty as a whole, but certain fields are characterized by considerable shifts. Of particular note are the declines for doctoral chemists, engineers, and physicists in the proportion under 40 years of age, representing average age increases of from 1.0 to 1.6 years in just a 2-year period. Computer specialists, who make up the smallest field studied, were, on the average, younger in 1975 than in 1973.

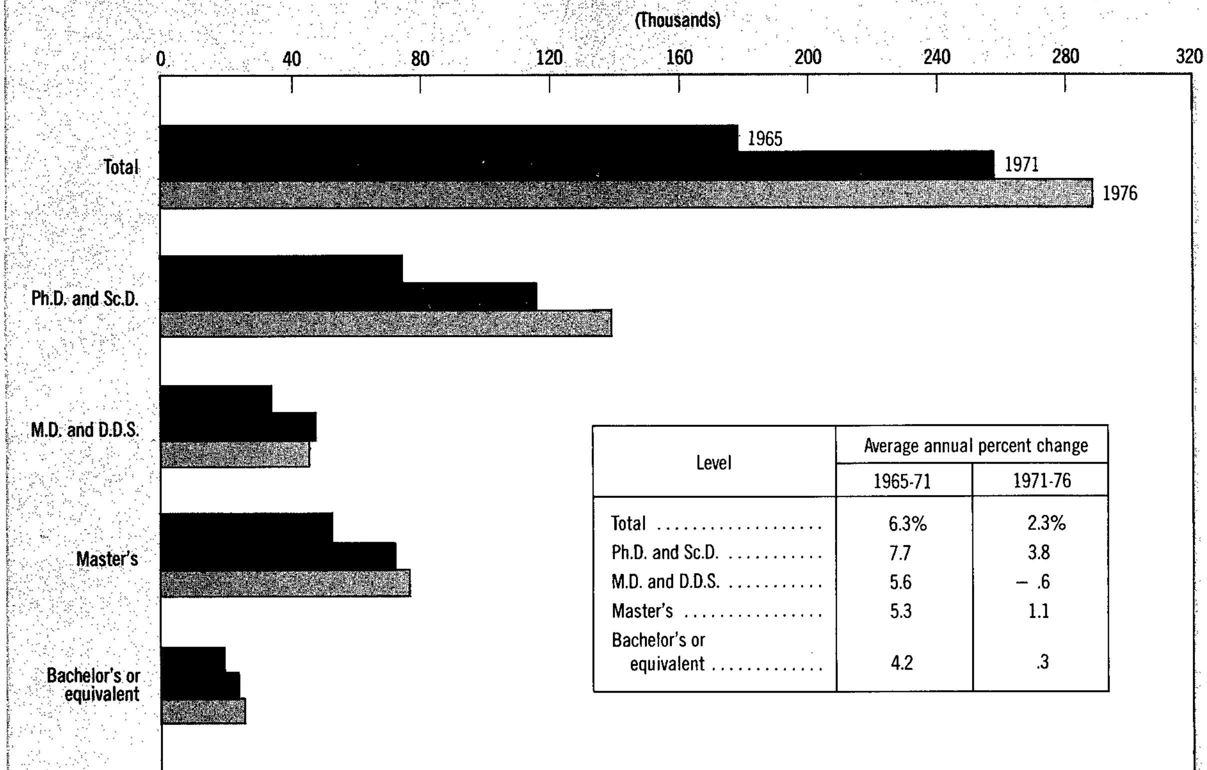
Another indicator of change in faculty characteristics is the proportion of full-time faculty at all colleges and universities with tenure. Figure 5-8 presents the 1974 distribution of tenured faculty in a sample of doctoral level science and engineering departments for 15 fields. Overall, 70 percent of these faculty had tenure in 1974, with the proportions ranging from 81 percent in chemical engineering to 59 percent in physiology.

Federal Government employment of scientists and engineers

The 160,000 scientists and engineers employed by the Federal Government represented about one of every ten scientists and engineers in 1974. Over the 1964-74 period, Federal employment of these workers has changed little in total, increasing by 17,000 or

5-5

Scientists and engineers employed in universities and colleges by level of attainment, 1965-76



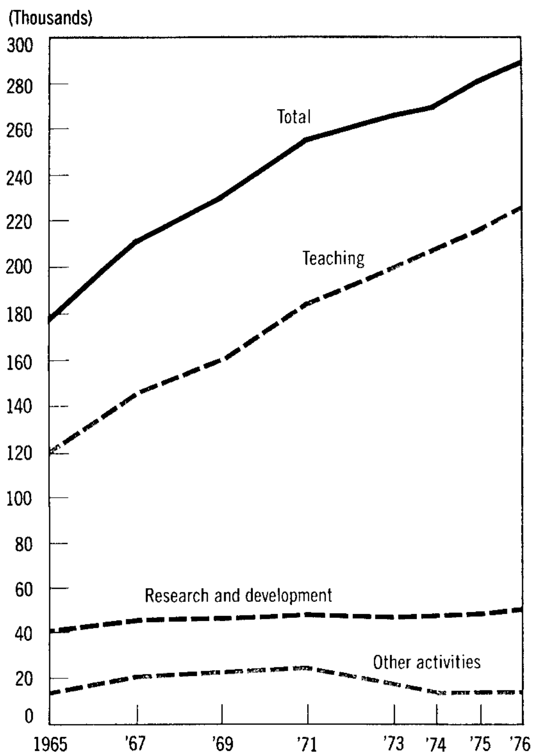
Level	Average annual percent change	
	1965-71	1971-76
Total	6.3%	2.3%
Ph.D. and Sc.D.	7.7	3.8
M.D. and D.D.S.	5.6	− .6
Master's	5.3	1.1
Bachelor's or equivalent	4.2	.3

REFERENCE: Appendix Table 5-3.

only 12 percent in 10 years. In contrast, the employment of scientists and engineers throughout the economy rose by almost 25 percent during this period.

The distribution of scientists and engineers in the Federal Government by major employing agency and field of science for 1964 and 1974 is shown in the tables 5-9 and 5-10. These data show that there has been little change in the relative share of employment by agency and little shift in the relative proportions employed in the scientific fields.

5-6
Academic scientists and engineers, by primary work activity, 1965-76



REFERENCE: Appendix Table 5-4.

Employment of scientists and engineers in nonprofit institutions

About 1 to 2 percent of the Nation's scientists and engineers are employed in the approximately 500 nonprofit institutions.[13] that allocated at least $100,000 each to intramural R&D programs in 1973. By 1973, employment of scientists and engineers in this sector had reached approximately 26,300, an increase of some 20 percent since 1965.[14]

In contrast to trends reported for the academic sector, virtually all of the increase in science and engineering personnel in these independent nonprofit institutions was attributable to the 90 percent who worked primarily in research and development.

[13] Including research institutes, hospitals, and the Federally Funded Research and Development Centers administered by nonprofit institutions.

[14] *R&D Activities of Independent Nonprofit Institutions, 1973*, National Science Foundation (NSF 75-308), p. 6.

5-7. Age of doctoral scientists and engineers employed at 4-year colleges and universities, 1973 and 1975

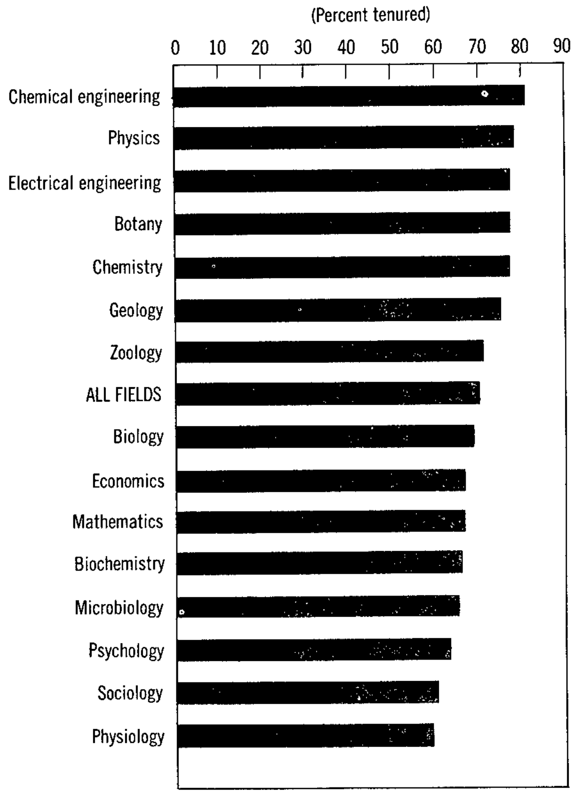
Field of employment	Median age (in years)		Percent under 40 years of age	
	1973	1975	1973	1975
Total	40.9	41.3	47	46
Physical scientists	39.1	40.4	54	49
Chemists	39.3	40.9	53	47
Physicists and astronomers	38.9	39.9	55	51
Mathematical scientists	37.8	38.6	59	57
Computer specialists	39.6	38.9	51	55
Environmental scientists[1]	40.1	41.0	47	46
Engineers	40.8	41.7	47	42
Life scientists	41.8	41.6	44	45
Biological scientists	41.0	40.3	47	49
Agricultural scientists	44.7	44.9	34	34
Medical scientists	42.0	42.4	43	42
Psychologists	40.9	41.3	47	46
Social scientists	43.0	42.9	40	40

[1] Includes earth scientists, oceanographers, and atmospheric scientists.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1975*, Detailed Statistical Tables (NSF 77-309), pp. 38-40, and unpublished data.

5-8

Tenured faculty as a percent of full-time faculty in a sample of doctorate-level science and engineering departments by selected fields, 1974



REFERENCE: Appendix Table 5-5.

5-9. Federal Government employment of scientists and engineers by agency, 1964 and 1974

Agency	1964	1974
All agencies Number (in thousands)	143	160
All agencies Percent	100	100
Department of Defense	44	44
Department of Agriculture	17	15
Department of Interior	9	9
National Aeronautics and Space Administration	9	7
Department of Commerce	5	5
Department of Health, Education, and Welfare	4	4
Other agencies	12	17

NOTE: Percents may not add to 100 because of rounding.

SOURCE: Civil Service Commission, unpublished data for 1964 and *Occupations of Federal White-Collar Workers* (SM 56-11), pp. 190-201 for 1974.

5-10. Federal Government employment of scientists and engineers by field, 1964 and 1974

Field	1964	1974
All fields Number (in thousands)	143	160
All fields Percent	100	100
Engineers	52	52
Life scientists	17	18
Physical scientists	18	17
Social scientists and psychologists	8	8
Mathematicians	4	4

NOTE: Percents may not add to 100 because of rounding.

SOURCE: Civil Service Commission, unpublished data for 1964 and *Occupations of Federal White-Collar Workers* (SM 56-11), pp. 190-201 for 1974.

RESEARCH AND DEVELOPMENT PERSONNEL

All R&D scientists and engineers

Approximately 531,000 scientists and engineers were engaged in R&D activities on a full-time-equivalent (FTE) basis[15] in 1975, 3,000 more than in 1974, and 9,000 more than the number employed in 1973. Approximately one-third of all FTE scientists and engineers are engaged in R&D activities.[16]

Increased employment of scientists and engineers in R&D in both 1974 and 1975 may signal the reversal of the downturn in employment which started in 1969. Between 1954 and 1969, employment of R&D scientists and engineers increased at an average annual rate of 5.9 percent, more than three times faster than the growth in total employment. Since 1969, total civilian employment has continued to increase, but the long-term growth trend for R&D scientists and engineers was ended as both the number of R&D scientists and engineers and R&D expenditures (in constant 1972 dollars) declined. Between 1969 and 1973, the employment of R&D scientists and engineers declined by approximately 37,000. As a result, the 1975 employment level was almost 28,000 lower than the peak employment level reached in 1969.

R&D in industry

The number of R&D scientists and engineers in industry in 1975—358,000 FTE—has increased only slightly since 1973. Employment of these scientists and engineers peaked in 1969 at 387,000, declined through 1972, and showed a small upturn in 1973. However, 1975 saw 8 percent fewer compared to 1969. In 1975, approximately two-thirds of all R&D scientists and engineers were in industry.[17]

About 30 percent of industrial R&D scientists and engineers were supported by Federal funds in January 1975 (Figure 5-11). This is a significant decrease from the 44 percent Federal share in 1967. The relative decrease in federally supported R&D scientists and engineers is most evident in the electrical equipment and communications, the aircraft and missiles, and the motor vehicle industries. About 3 of every 4 of the federally supported R&D scientists and engineers in industry are employed in the

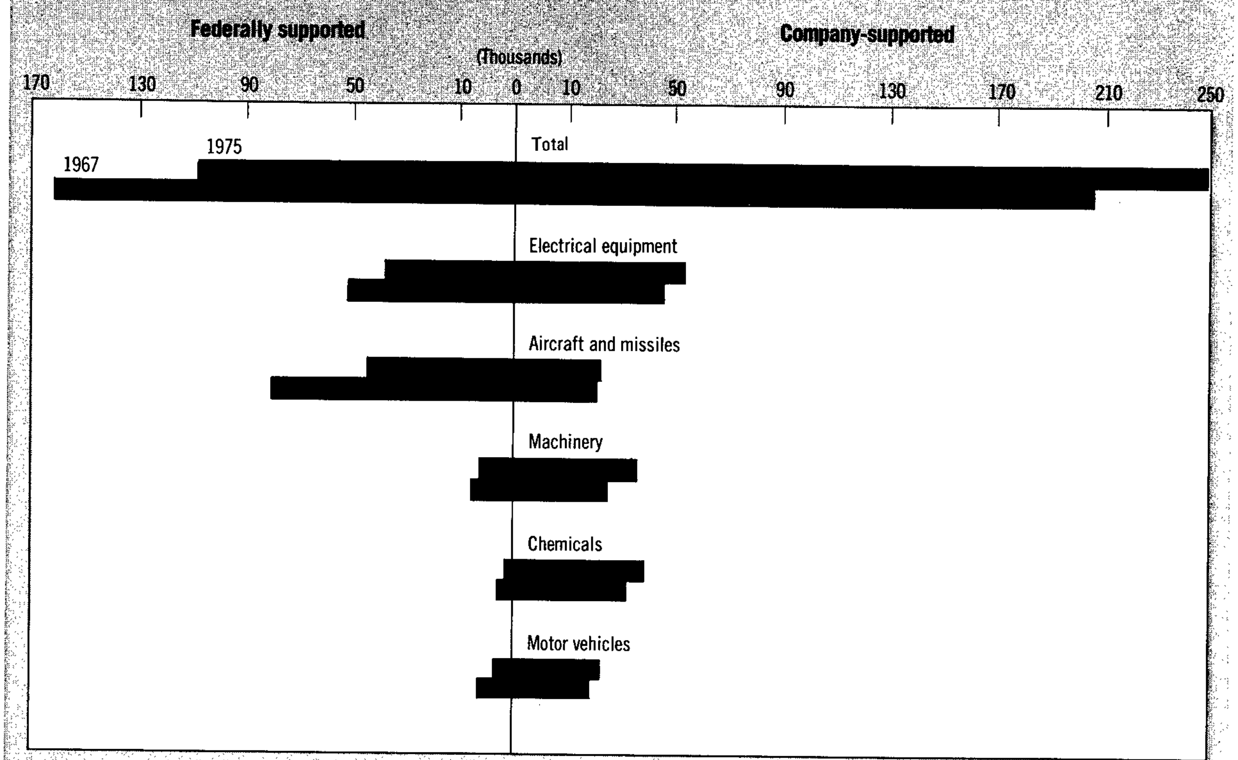
[15] Full-time-equivalent data combine the number of full-time employees with the number of part-time employees expressed as their equivalent in full-time employees.

[16] *National Patterns of R&D Resources, 1953-1976,* National Science Foundation (NSF 76-310), p. 32.

[17] These and other aspects of industrial R&D are covered more fully in the chapter on "Industrial R&D and Innovation."

5-11

R&D scientists and engineers[1] employed in selected industries by source of support, 1967 and 1975



[1] Full-time-equivalent basis as of January.
REFERENCE: Appendix Table 5-6.

electrical equipment and communications and the aircraft and missiles industries.

R&D in the academic sector

In 1976, universities and colleges employed approximately 72,400 FTE R&D scientists and engineers, including graduate students employed as scientists and engineers. This represents almost 30 percent of their total FTE scientists and engineers. The 18,900 graduate students working as R&D scientists and engineers represented an estimated 26 percent of the total university and college R&D work force.

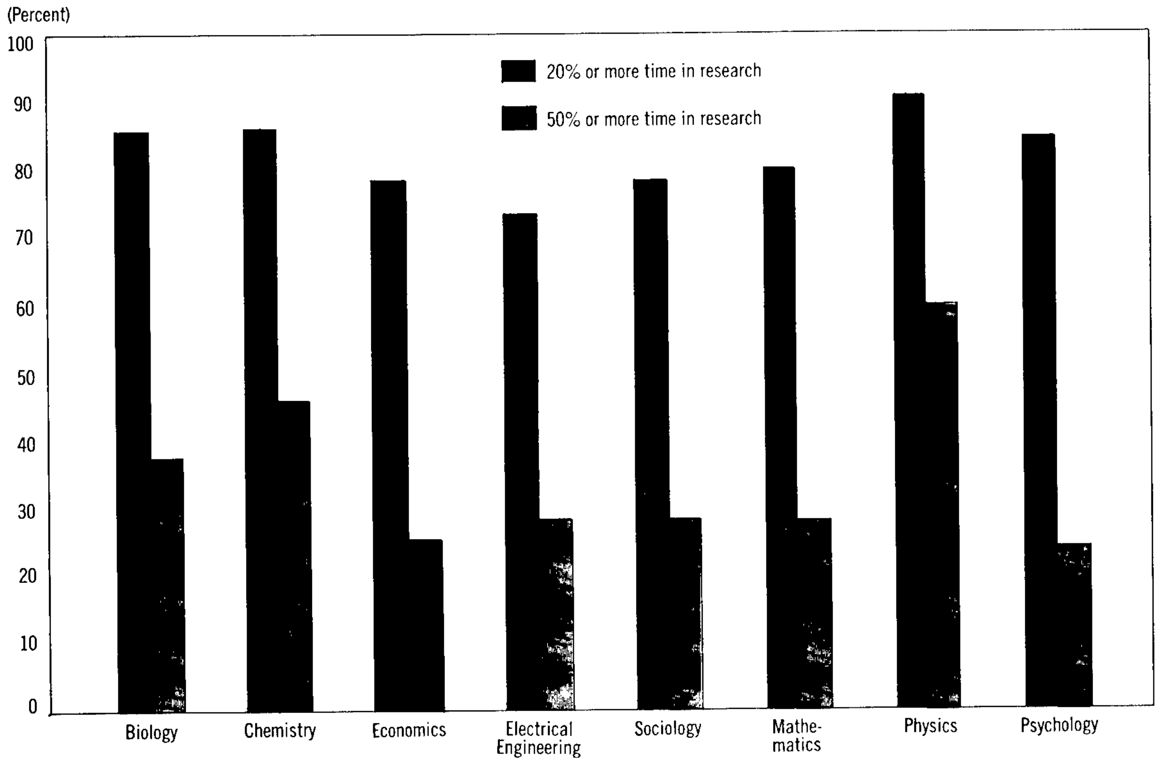
Many R&D scientists and engineers in universities and colleges have teaching as a primary work activity and R&D as a secondary activity. Over 60 percent of the science and engineering doctorates employed by universities and colleges were engaged in R&D as a primary or a secondary activity, according to a 1973 survey.[18]

In 1975, about 84 percent of the full-time science and engineering doctorate faculty in a large sample of doctorate-granting departments spent at least 20 percent of their time in research, while 38 percent spent 50 percent or more of their time in research. Figure 5-12

[18] National Science Foundation, unpublished data.

5-12

Proportion of time spent in research by full-time doctorate faculty in selected science and engineering fields at a sample of institutions, 1975



REFERENCE: Appendix Table 5-7.

shows faculty research involvement in selected fields.[19] For the fields and institutions included in the sample, faculty in biochemistry had the highest rate of participation at both the 20 percent level and the 50 percent level of research involvement.[20]

Academic scientists and engineers engaged in R&D are primarily involved in research rather than development. In 1976, 96 percent of academic R&D funding was expended for research activities (basic and applied), with only 4 percent reported for development activities.[21]

In all science and engineering fields of a recent study, the proportion of young, doctoral R&D scientists and engineers has dropped significantly (Figure 5-13). The greatest shift from 1968 to 1974 occurred in electrical engineering and physics, while the least changed fields were sociology, psychology, and biology. In 1975, physics and biochemistry had the lowest rate of

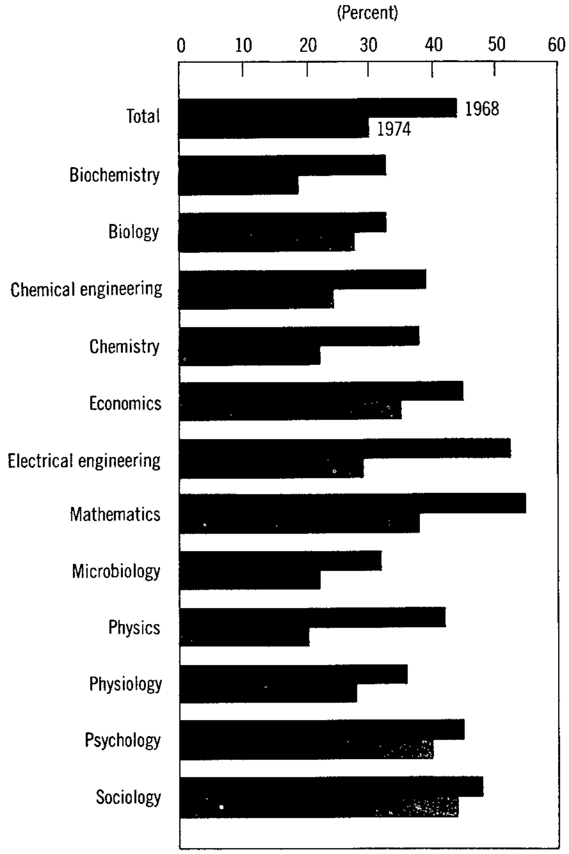
[19] It is difficult to measure with precision the percent of a faculty scientist's time or effort which can be assigned to research because of the inseparability of research and teaching, particularly at the graduate level. These allocations were made by department chairpersons.

[20] Frank J. Atelsek and Irene L. Gomberg, *Faculty Research: Level of Activity and Choice of Area* (Washington, D.C.: American Council on Education, 1976), p. 12.

[21] *National Patterns of R&D Resources, 1953-1976*, National Science Foundation (NSF 76-310), derived from pp. 4-5.

5-13

Young [1] doctoral faculty investigators [2] as a percent of all doctoral faculty investigators in a sample of doctorate-granting institutions by selected fields, 1968 and 1974



[1] Those who had held doctorates seven years or less at the time of each study.
[2] Spending 20 percent or more of their time in research.
REFERENCE: Appendix Table 5-8.

young R&D scientists, while psychology and sociology were the fields with the highest proportion of young scientists.

Almost 40 percent of the full-time doctorate faculty investigators had no external separately budgeted research support in 1975 (see Table 5-14). Among the 62 percent of the investigators who had such support, some 9 percent received external support primarily for research in an area different from their preferred area. Mining and mineral engineering faculty received the highest percentage of external support. Sociologists received a relatively low level of external support, 45 percent, and 17 percent of those accepted support in an area different from their preferred area of research.

For the 15 selected fields listed in Table 5-15, more than one-half of the faculty investigators were doing research directly connected with Federal grants and contracts. In 1968, however, two-thirds of faculty investigators were involved in Federal projects. Large differences, however, exist among the several scientific fields. For example, more than three-fourths of the faculty investigators in biochemistry, but only one-fourth of those in sociology, were doing research connected with federally supported projects in 1974.

5-14. Research support for full-time doctorate faculty investigators[1] in selected science and engineering fields at a sample of institutions, 1975

Selected fields	Percent with external support	Percent with external support which is different from preferred area[2]
Total	62	9
Biochemistry	80	4
Biology	68	10
Botany	64	17
Chemical engineering	80	12
Chemistry	74	9
Economics	39	16
Electrical engineering	74	16
Geology	70	11
Mathematics	43	3
Microbiology	80	8
Mining and mineral engineering	88	11
Physics	71	5
Physiology	78	5
Psychology	44	8
Sociology	45	17
Zoology	61	11

[1] Those spending 20 percent or more of their time in research, as estimated by department chairpersons.

[2] "Preferred area of research" was defined as the research field a faculty member would have chosen to work in, if support had been available.

SOURCE: Frank J. Atelsek and Irene L. Gomberg, *Faculty Research: Level of Activity and Choice of Area* (Washington, D.C.: American Council on Education, 1976), p. 13.

5-15. Proportion of faculty investigators performing R&D connected with Federal grants and contracts by selected fields, 1974

Selected fields	Percent whose research was Federally supported
Total	56
Biochemistry	78
Physiology	75
Microbiology	74
Physics	72
Electrical engineering	71
Chemical engineering	65
Biology	62
Geology	59
Chemistry	58
Zoology	52
Psychology	43
Mathematics	42
Botany	42
Economics	30
Sociology	26

SOURCE: National Science Foundation, *Young and Senior Science and Engineering Faculty, 1974: Support, Research Participation, and Tenure* (NSF 75-320), p. 5.

DOCTORAL SCIENTISTS AND ENGINEERS

Resources devoted to the education and training of doctoral scientists and engineers are significant, in both monetary terms and in the amount of time involved. More importantly, scientists and engineers holding doctoral degrees are the most highly trained of our Nation's scientific and engineering personnel. Thus, they provide a large part of the leadership of the entire scientific and technical effort. For these reasons, the utilization and characteristics of this group require careful monitoring.

It is estimated that in 1975 there were 278,000 doctoral scientists and engineers in the United States, an increase of 36,000 or 13 percent over the number reported in 1973.[22] During this 2-year period, the relative increase in the number of women doctorate holders in science and engineering exceeded that of men. Thus, while the number of men increased by 12 percent, the increase by women was almost twice as large (23 percent). The proportion of women in the doctorate level science and engineering population rose from 8.7 percent in 1973 to 9.4 percent in 1975.[23]

The physical and life sciences accounted for almost half of the 1975 population of doctoral scientists and engineers, as shown in Table 5-16. There were no significant changes from 1973 to 1975.

5-16. Distribution of doctoral scientists and engineers by selected fields, 1973 and 1975

Field	Percent 1973	Percent 1975
Total	100	100
Physical scientists	22	21
Mathematical scientists and computer specialists	7	7
Life scientists[1]	26	26
Environmental scientists[2]	5	5
Engineers	15	16
Psychologists	12	11
Social scientists	13	14

[1] Includes biological, medical and agricultural scientists.
[2] Includes earth scientists, oceanographers and atmospheric scientists.

REFERENCE: Appendix Table 5-9.

Sectors of doctoral employment

The pattern of employment of doctoral scientists and engineers in 1975 is shown in Figure 5-17. Doctoral scientists were predominantly employed by educational institutions (63 percent); within this group 61 percent were employed by 4-year colleges and universities and 2 percent by 2-year colleges. During the period 1966-75, there was a change in the proportions of doctoral scientists employed by business and by educational institutions, the former declining and the latter increasing. However, in view of enrollment trends and financial problems of institutions of higher education, this shift is not expected to continue. Doctoral engineers exhibited a different pattern of employment from scientists; over half of them were employed in the industrial sector in 1975.

The overall proportion of young[24] doctoral faculty in a selection of doctorate-granting science and engineering departments decreased substantially from 1968 to 1975, dropping from 43 percent to 27 percent of the total doctoral faculty.[25] For the fields shown in Table 5-18, the total number of full-time faculty increased by 10 percent from 1968 to 1975. However, the young doctorate faculty proportion declined in all seven fields while even the absolute numbers of young doctorate faculty decreased in all fields except biology.

Age distributions among doctoral scientists and engineers, however, do not differ greatly by employment sector (Figure 5-19), although doctoral scientists and engineers working for the Government had a slightly higher median age than these other two groups, apparently caused by a lessening of the proportion under 40.

The relatively small proportion of employed doctorates under the age of 30 can be accounted for in part by the time required to attain a doctorate. In recent years, the median time lapse

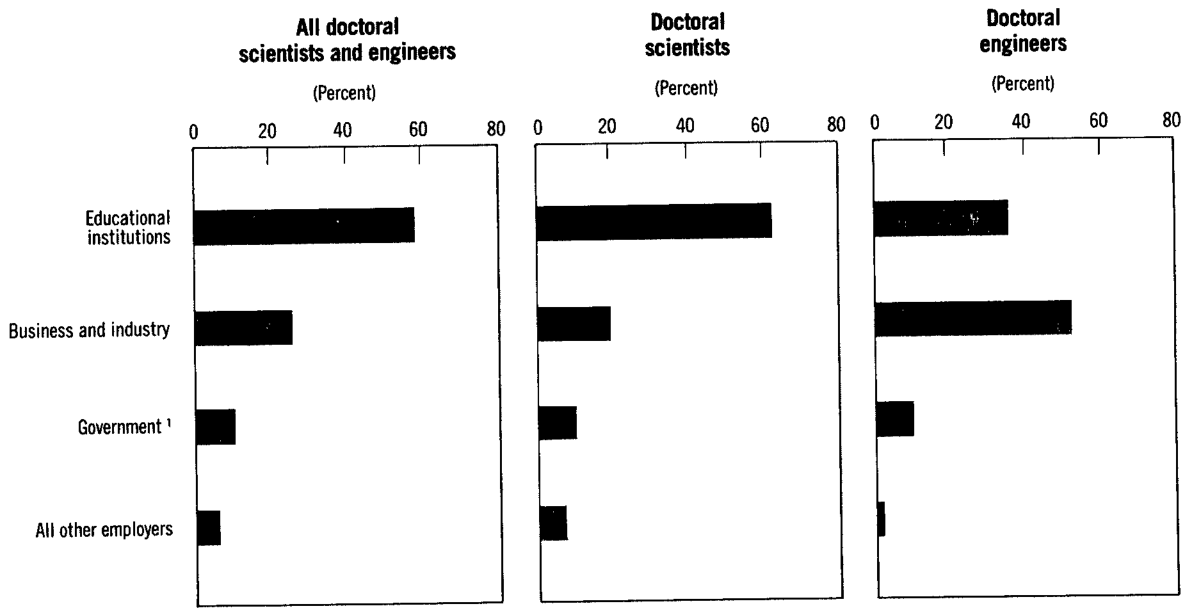
[22] *Characteristics of Doctoral Scientists and Engineers in the United States, 1975*, National Science Foundation (NSF 77-309), p. viii.

[23] *Ibid.* For further information on this topic, see the subsequent section in this chapter entitled "Women and Minorities in Science and Engineering."

[24] Those who had held a doctorate degree for 7 years or less at the time of each study.

[25] Frank J. Atelsek and Irene Gomberg, *Young Doctorate Faculty in Selected Science and Engineering Departments, 1975 to 1980*, (Washington, D.C.: American Council on Education, 1976), p. 14.

5-17
Percent distribution of employed doctoral scientists and engineers by employment sector, 1975



[1] Includes the military and Commissioned Corps of the Public Health Service.
REFERENCE: Appendix Table 5-10.

5-18. Young[1] doctorate faculty as a percent of total full-time doctorate faculty in matched[2] doctorate-level science and engineering departments, 1968-75

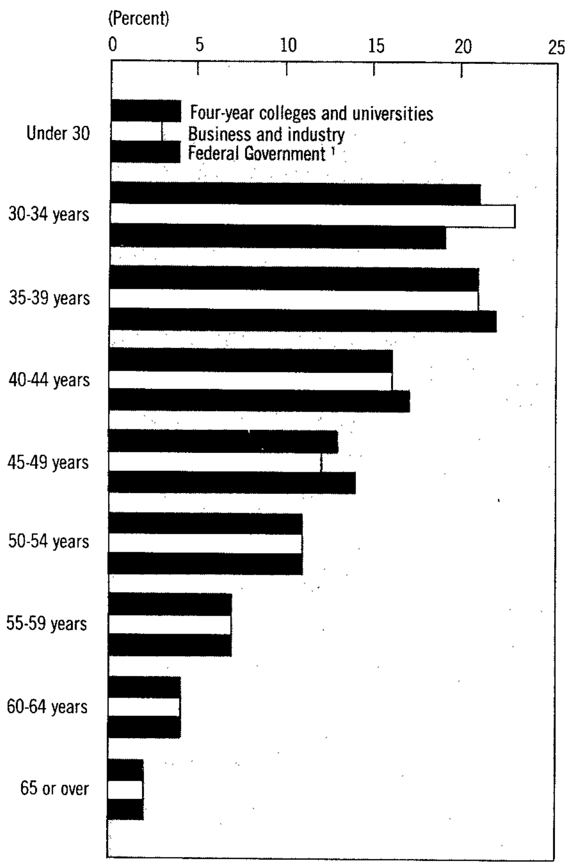
Selected fields	Spring 1968	Spring 1974	December 1975
Biology	31	27	28
Chemistry	35	21	20
Economics	44	33	33
Electrical engineering	51	27	25
Mathematics	52	36	30
Physics	41	20	18
Psychology	45	41	36

[1] Those who held doctorates for 7 years or less at the time of each study.
[2] "Matched" indicates that the same departments were surveyed in 1968, 1974, and 1975.

SOURCE: Frank J. Atelsek and Irene Gomberg, *Young Doctorate Faculty in Selected Science and Engineering Departments, 1975 to 1980* (Washington, D.C.: American Council on Education, 1976), p. 14.

5-19

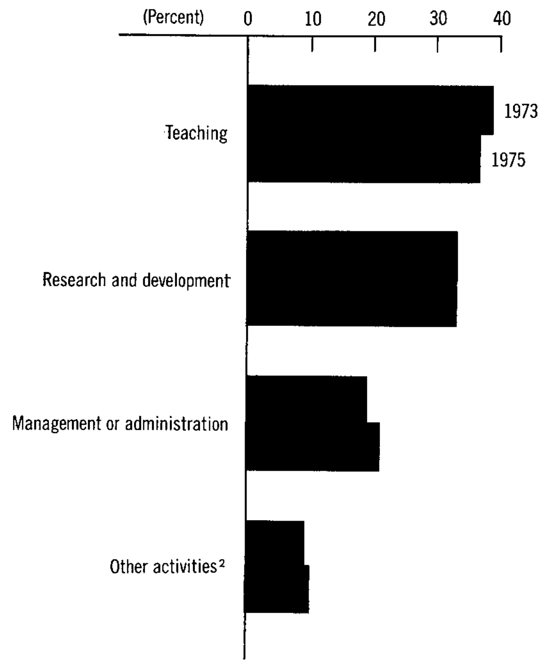
Doctoral scientists and engineers by age and type of employer, 1975



[1] Includes the military and Commissioned Corps of the Public Health Service.
REFERENCE: Appendix Table 5-11.

5-20

Distribution of employed doctoral scientists and engineers by primary work activity,[1] 1973 and 1975



[1] Primary work activity is defined as that type of work occupying the largest portion of time.
[2] Includes consulting, sales, and other professional service activities.
REFERENCE: Appendix Table 5-12.

between the baccalaureate and the doctorate has been 7 years.[26]

Primary work activities of doctoral scientists and engineers

The activities in which employed doctoral scientists and engineers were *primarily* involved are indicated in Figure 5-20. The data do not show the time allocated among the several activities of doctoral scientists and engineers, but rather the activity they reported as occupying the largest portion of their time. Teaching and R&D represent the primary work activities of doctoral scientists, the majority of whom are employed in universities and colleges, while doctoral engineers were working predominantly in R&D and management.

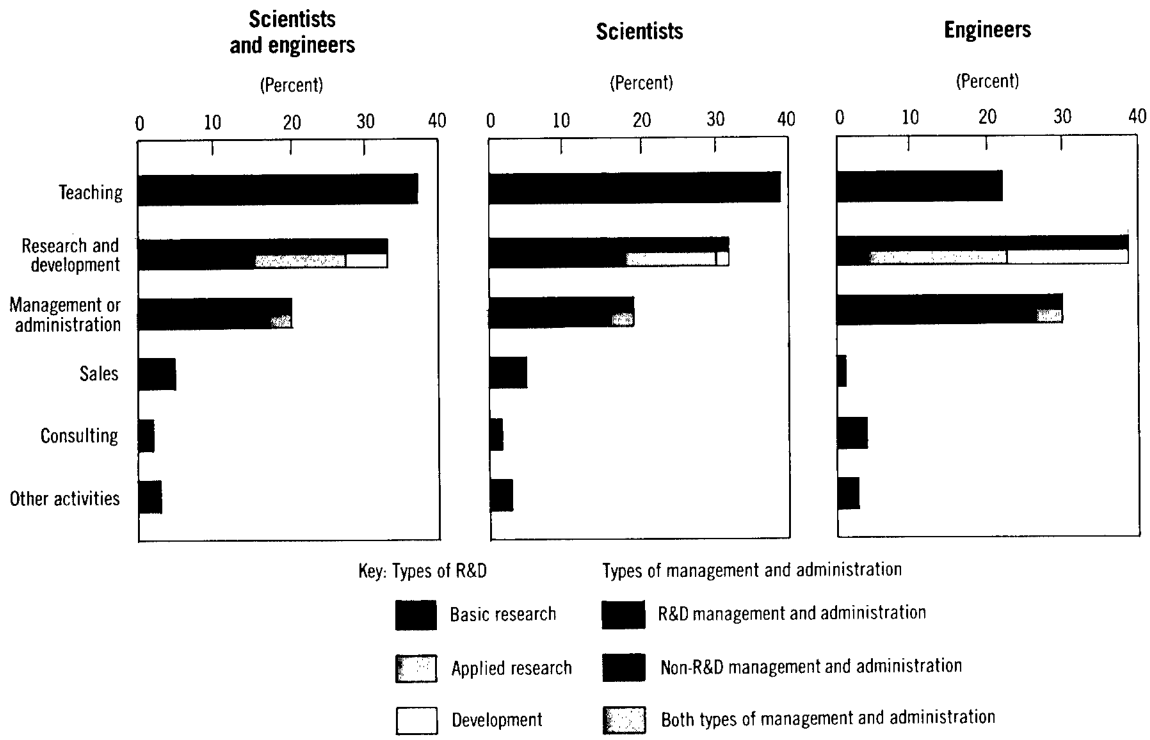
Of the 32 percent of the doctoral scientists primarily engaged in R&D in 1975 (Figure 5-21), 55 percent were working in basic research, 37 percent were involved in applied research, and only the small balance in development and design. The number of doctoral scientists primarily engaged in R&D management activities, however, has reached the equivalent of over one-half of the total number primarily involved in basic research (21,200 and 37,500, respectively).

In contrast, of the 39 percent of the doctoral engineers who were primarily engaged in R&D

[26] *Doctorate Recipients from U.S. Universities: Summary Report*, National Academy of Sciences, annual series.

5-21

Percent distribution of employed doctoral scientists and engineers by primary work activity,[1] 1975



[1] Primary work activity is defined as that type of work occupying the largest portion of time.
REFERENCE: Appendix Table 5-3.

in 1975, less than 10 percent were working in basic research, 49 percent in applied research, and 41 percent in development. Almost five times as many doctoral engineers were primarily involved in the management of R&D than in basic research.

Doctoral scientists and engineers in R&D

Approximately 113,800 of the science and engineering doctorates in the 1975 U.S. labor force cited R&D or R&D management as their primary work activity, up 18 percent since 1973.[27] While some one-third of all scientists and engineers in the labor force were engaged in performing R&D, the proportion of those with doctorates who were primarily involved in all R&D-related work was 43 percent.

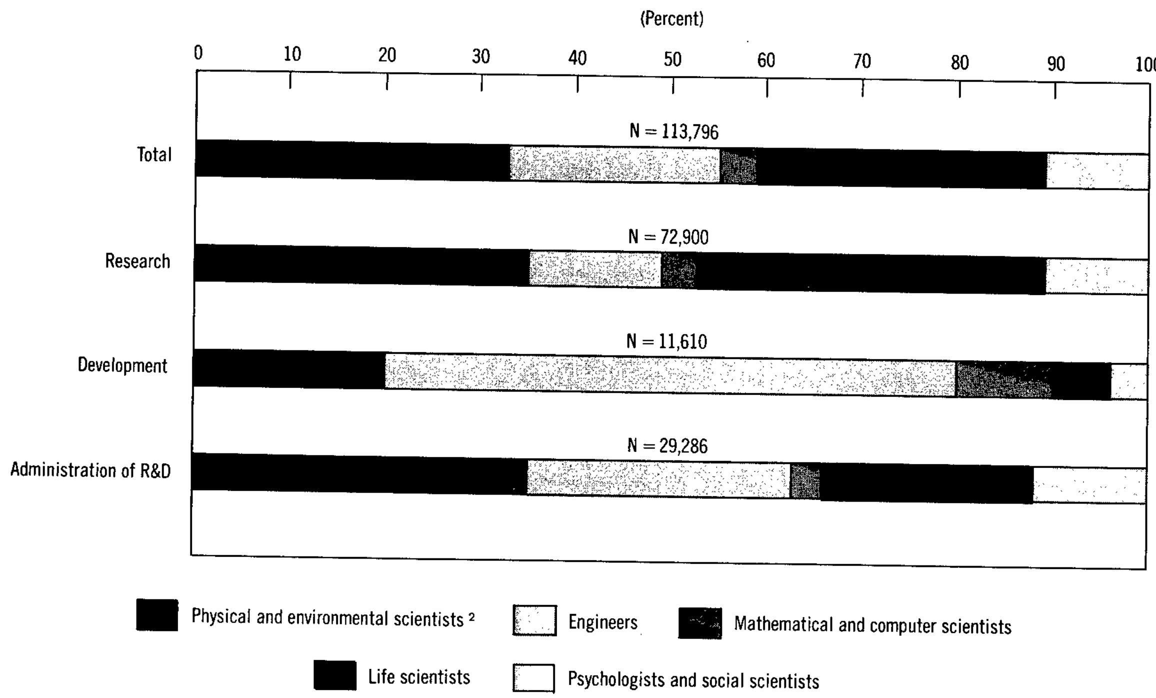
The 1975 distribution of these scientists and engineers by field of science and work activity is shown in Figure 5-22. Engineers represent the major portion of those with development as a primary work activity, while physical and life science doctorates constitute the major portion of those involved in research. Over one-fourth of R&D doctorates spend the major part of their time in R&D administration.

In 1975 distribution of R&D doctorates by type of employer is shown in Figure 5-23. In contrast to the pattern for all R&D scientists and engineers, the doctorates were about equally concentrated in industry and educational institutions, for all fields combined. Information on their distribution by type of employer for

[27] *Characteristics of Doctoral Scientists and Engineers in the United States, 1975*, National Science Foundation (NSF 77-309), p. 6 and unpublished data.

5-22

Distribution of employed doctoral scientists and engineers [1] by type of R&D activity and by field, 1975



[1] Those whose primary work is R&D or R&D management.
[2] Environmental scientists includes earth scientists, oceanographers, and atmospheric scientists.
REFERENCE: Appendix Table 5-14.

major science fields is presented in Figure 5-24. Physical science, engineering, and computer specialist R&D doctorate personnel were most heavily concentrated in industry, while doctoral life scientists, mathematical scientists, and social scientists were located predominantly in educational institutions.

The proportion of doctorate-holders involved primarily in R&D varies considerably from one sector to another. Almost three-quarters of the doctorates employed in industry were engaged primarily in R&D or R&D management in 1975, while the R&D involvement of doctorates employed in government was slightly higher. In academic institutions, where teaching is the chief activity, slightly more than one-fourth of the doctorates were working primarily in R&D.[28]

[28] *Ibid.*, p. 50.

Field mobility of doctoral scientists and engineers

Not all doctoral scientists and engineers remain employed in the field in which they received their doctorate.[29] In 1975, one out of every six employed doctoral scientists and engineers was employed in a field different from his doctoral field.[30] This is an important consideration in estimating and interpreting supply and utilization data.

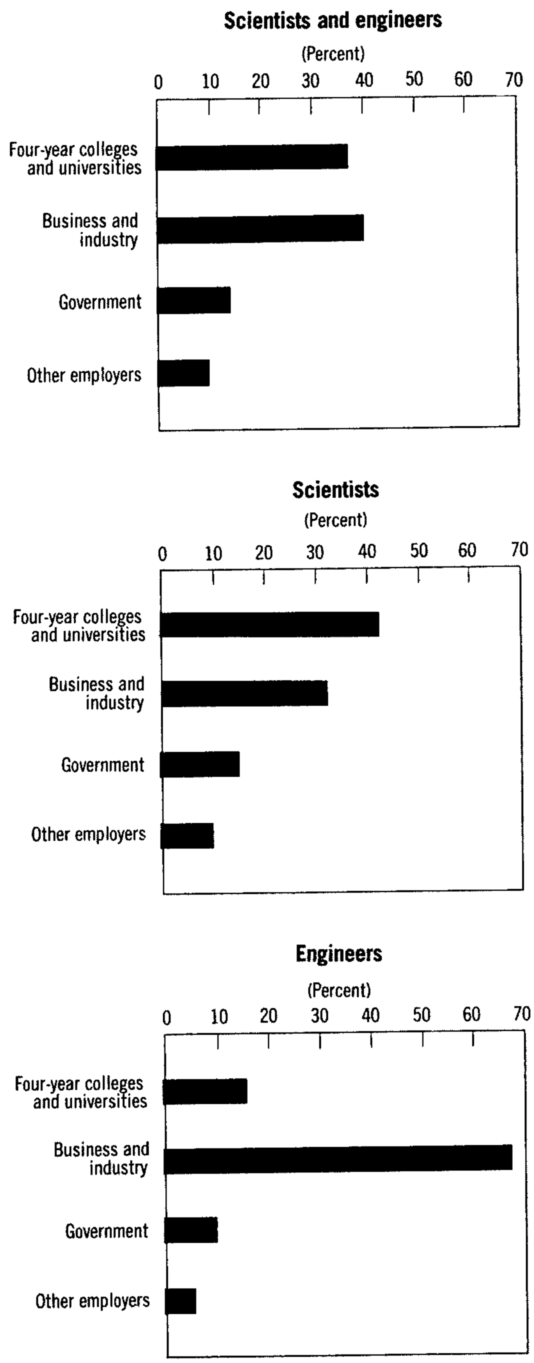
Field mobility or changing varies considerably among disciplines. The fields of the life sciences,

[29] Working in another field, however, does not mean that the original training is unrelated, e.g., the nuclear physicist who is employed in nuclear engineering. Some 15-25 percent of those who have switched broad fields are estimated to be working in fields for which they had received relevant training.

[30] *Doctoral Scientists and Engineers in the United States, 1975 Profile*, National Academy of Sciences, 1976, p. 9.

5-23

Doctoral R&D scientists and engineers [1] by type of employer, 1975



[1] Those whose primary work activity is R&D or R&D management.
REFERENCE: Appendix Table 5-15.

mathematics, and psychology experience the highest retention rates, with approximately 90 percent of the employed doctorate recipients in these fields still employed in the field of their doctorate. Physics and chemistry have the lowest retention rates for employed doctoral scientists, approximately 70 percent.

The largest number of doctoral physicists who switched fields were employed in engineering, while the largest number of doctoral chemists who had changed fields were employed in the biosciences or only slightly less often in physics. However, relatively few doctoral engineers and life scientists have switched to physics and chemistry.

The proportion of doctoral scientists and engineers employed in nonscience occupations in 1975 varies from about 11 percent of those trained in the social sciences to about 2 percent of those trained in the life sciences.

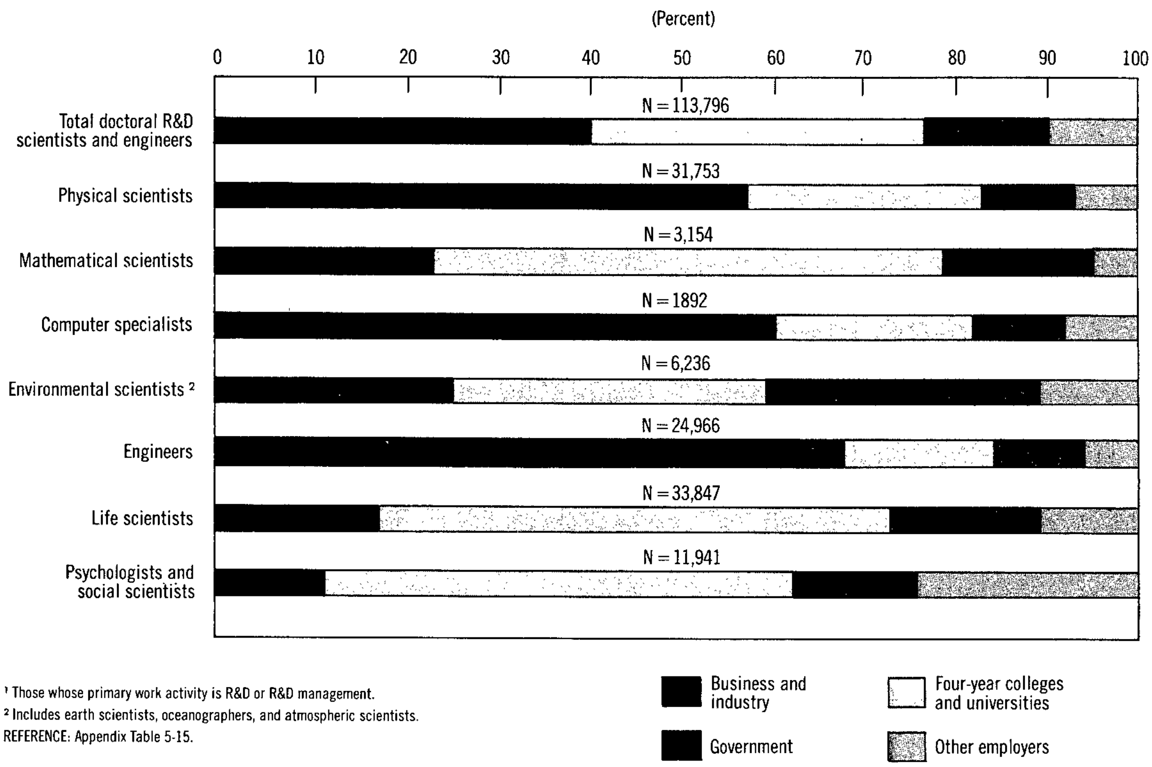
Salary levels, availability of employment, and the desire for additional responsibility are only a few of the many factors that may influence an individual to leave the field of his doctorate to enter a different, often unrelated, field of employment. Firm information, however, is not available on why scientists switch fields. For example, the earth science field has experienced the greatest proportional increase due to field switching. There are between four and five times as many doctoral scientists who switched into the earth sciences as there are scientists who were trained in the earth sciences and have switched to a different field. This net in-migration to the earth sciences may be the result of federally funded programs designed to study environmental problems. However, this cannot be substantiated since the available data do not indicate when the bulk of the field switching occurred, except that those receiving the doctoral degrees recently (1974) have only a 2-to-1 ratio of net in-migration.

The fields of mathematics and psychology have also experienced a significant net growth over the years. There were more than twice as many nonmathematics and nonpsychology doctorate recipients who entered employment in these areas than mathematics and psychology doctorate recipients who left these fields. Chemistry, physics, and the social sciences, on the other hand, have lost substantial portions of their doctorate population.

Field switching varies with the number of years since an individual earned the doctorate. In

5-24

Distribution of doctoral R&D scientists and engineers [1] by field and by type of employer, 1975



[1] Those whose primary work activity is R&D or R&D management.
[2] Includes earth scientists, oceanographers, and atmospheric scientists.
REFERENCE: Appendix Table 5-15.

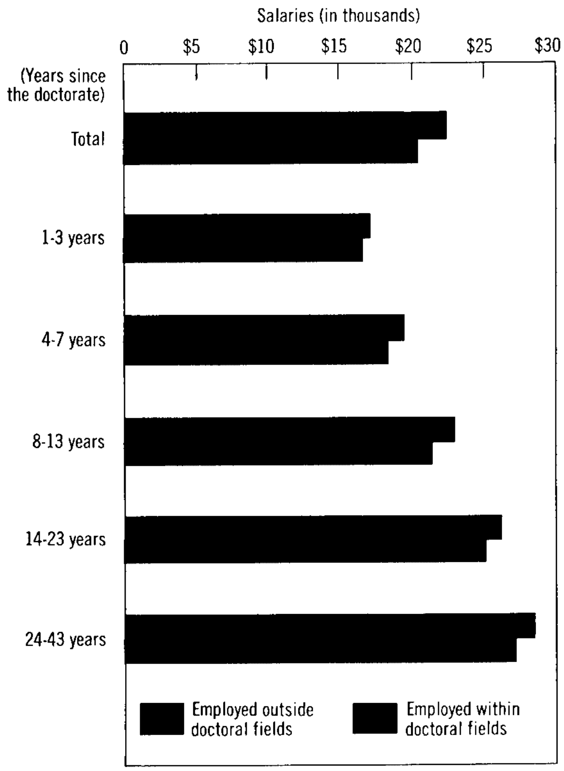
general, the more recent doctorate recipients show a lesser tendency to change fields, having had less time to consider other options or perhaps having narrower specializations. The 1972 doctorate recipients in the earth sciences are an exception. An unusually large proportion of them were employed in physics, engineering, and life science fields.

Doctoral scientists and engineers employed in a field other than their doctorate fields generally earn more than those remaining in their doctorate field (Figure 5-25). Those who changed fields had median salaries about $1,800 (9 percent) higher than those who did not. Salary differences varied with the number of years since the doctorate; the difference for the most recent graduates (those receiving doctorates in the 1970-72 period) was $600 compared to $1,400 for those with doctorates earned before the late 1940's.

Those trained as mathematicians who left their doctoral field showed the largest salary differences in 1973. Thus, those who had received a degree in mathematics and were working in the same field had median salaries of $19,300. Those trained as mathematicians but working in another field had median salaries of $24,200, a difference of almost $5,000.

5-25

Median annual salaries of doctoral scientists and engineers whose fields of employment differed from their doctoral fields, by number of years since the doctorate, 1973



REFERENCE: Appendix Table 5-16.

WOMEN AND MINORITIES IN SCIENCE AND ENGINEERING

Women in science and engineering

Of the nearly 2 million persons in the science and engineering population in 1974, about 185,000 (9 percent) were women.[31] Of these, only 7,600 were in engineering fields. The social sciences have the largest number of women (56,000), followed by the life sciences (34,100).

Almost half of all female scientists and engineers (87,000 or 47 percent) were not in the labor force in 1974, i.e., they were not employed and were not seeking employment. Of those not in the labor force, over 40,000 were social scientists, and over 15,000 were life scientists. By way of contrast, only about 12 percent of the male scientists and engineers were not in the labor force in 1974, and almost 30 percent of them were engineers.

Only about 6 percent of the employed scientists and engineers in 1974 were women. In that same year, however, women represented almost 40 percent of total civilian employment, and about 50 percent of the category "professional and technical workers."[32] The proportion of women employed in the various science and engineering fields varies widely as shown in Table 5-26.

5-26. Women scientists and engineers as a percent of total employment by field, 1974

Fields	Women as a percent of all employed scientists and engineers
All fields	6
Psychologists	25
Social scientists	13
Mathematical scientists	15
Life scientists	13
Computer specialists	17
Physical scientists	10
Environmental scientists[1]	4
Engineers	.5

[1] Includes earth scientists, oceanographers, and atmospheric scientists.

SOURCE: National Science Foundation, *U.S. Scientists and Engineers: 1974* (NSF 76-329), p. 19.

Women were more highly represented among psychologists, mathematical scientists and computer specialists, and had a lower representation among engineers and environmental and physical scientists. Overall, in 1974 women represented less than 1 percent of the engineers but 14 percent of all scientists in contrast to only about 8 percent of the scientist labor force in 1968.

Full-time employment of women scientists and engineers in the academic sector shows a

[31] *U.S. Scientists and Engineers: 1974*, National Science Foundation, (NSF 76-329).

[32] *Employment and Training Report of the President*, Department of Labor, 1976.

somewhat different pattern.[33] In 1976, 16 percent of the scientists and engineers employed full-time at colleges and universities were women—17 percent of the scientists and 2 percent of the engineers. The proportion of women in each field varies widely, as shown in Table 5-27.

In 1976, women made up 20 percent or more of both life scientists and psychologists, but less than 9 percent of the physical and environmental scientists in colleges and universities. The fields showing the greatest change from 1974 to 1976 were biological sciences (up 1,250 from 18 to 20 percent women), psychology (up almost 800, from 21 to 24 percent), and the social sciences (up almost 1,500, from 16 to 18 percent). In the case of doctorate-granting institutions alone, the percentage of women is similar to all institutions with the exception of chemistry and mathematics.

Besides the growth in the number of women in science alone between 1968 and 1974, the most striking difference during this period is the distribution of women scientists among types of employers.[34] In 1968, 52 percent of the women scientists were employed by educational institutions, but by 1974 the proportion had declined to 25 percent. There was a similar, though less dramatic, drop for the proportion of men scientists working in educational institutions (38 to 26 percent). The proportion of women working in business and industry more than doubled between 1968 and 1974, from 12 to 30 percent, and a larger proportion of women were working for Federal, State, and local governments in 1974 than in 1968. These changes took place partly because institutions of higher education were doing relatively little hiring over the period, and partly because jobs were being opened up to women in business and industry.

Women in graduate education

The number of women students enrolled for master's and doctoral degrees in science and

[33] Data for women scientists employed part-time are not available.

[34] *U.S. Scientists and Engineers: 1974*, National Science Foundation (NSF 76-329), p. 26 and *American Science Manpower, 1968*, National Science Foundation (NSF 69-38), based on pp. 29 and 43.

5-27. Women scientists and engineers employed full-time by universities and colleges by field, 1976

Field	All institutions: Number of women	All institutions: Percent women in each field	Doctorate institutions: Number of women	Doctorate institutions: Percent women in each field
All scientists and engineers	35,929	16	22,940	15
Engineers	447	2	372	2
Physical scientists	2,121	8	944	6
Chemists	1,521	11	618	8
Physicists	402	4	192	3
Other physical scientists	198	9	134	9
Environmental scientists[1]	379	5	243	5
Mathematical scientists	3,093	13	1,050	10
Life scientists	18,679	20	15,018	19
Agriculture	1,417	11	1,342	12
Biological	6,987	20	4,710	20
Medical	10,275	23	8,966	21
Psychologists	3,977	24	1,617	22
Social scientists[2]	7,233	18	3,696	17

[1] Includes earth scientists, oceanographers, and atmospheric scientists.
[2] Excluding historians.

SOURCE: National Science Foundation, *Manpower Resources for Scientific Activities at Universities and Colleges, January 1976: Detailed Statistical Tables* (NSF 76-321), pp. 14, 19, and unpublished data.

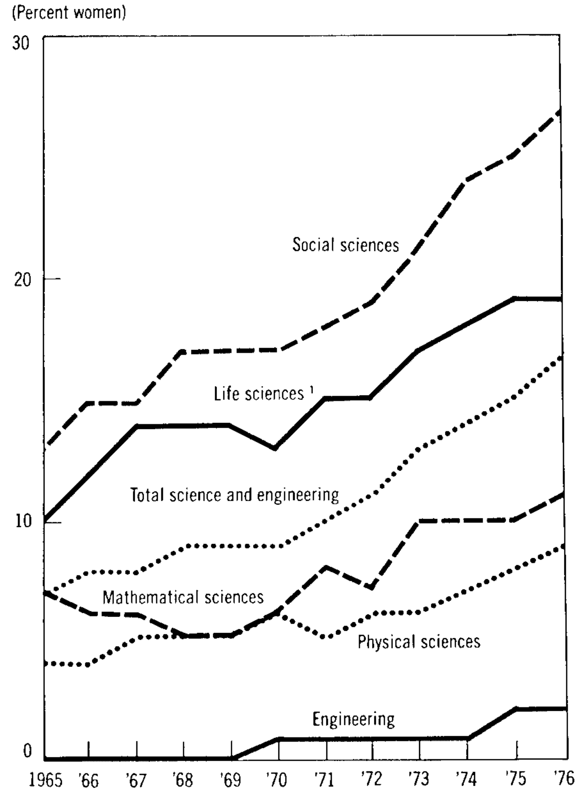
engineering doubled between 1966 and 1975.[35] The proportion of women enrolled for advanced degrees in various fields is shown in Table 5-28. The social sciences have had the greatest change in percent of total enrollment, while engineering has had the smallest.

The share of doctorate degrees in science and engineering received by women is also increasing (Figure 5-29). About 3,000 women earned doctorate degrees in science and engineering in 1976, compared to about 750 degrees awarded to women in 1965. Besides growing in absolute terms, the proportion of doctoral degrees in science and engineering earned by women increased from 7 percent of the total in 1965 to 17 percent in 1976. By 1976, women were awarded 27 percent of the doctorates in the social sciences and 19 percent in the life sciences, but 11 percent or less in the mathematical sciences, physical sciences, and engineering.[36]

One factor which may affect the participation of women in science and engineering is the difference in salary levels for men and women in science occupations, as in many professional and technical occupations. Among doctoral scientists and engineers, the 1975 median annual salary of $19,000 for women was 19 percent lower than the median of $23,500 for men.[37] Women's median salaries in 1975 were consistently below men's at each age level, regardless of the number of years of professional experience. Their salaries increased only 8 percent from 1973 to 1975, compared to an 11 percent rise in men's salaries. Recent data indicate that the gap in

5-29

Women as a percent of total science and engineering doctorate recipients by field, 1965-75



¹ Includes environmental sciences.
REFERENCE: Appendix Table 5-17.

[35] *Students Enrolled for Advanced Degrees*, National Center for Educational Statistics, annual series, and National Science Foundation, unpublished data.

[36] For more information on this topic, see Joseph L. McCarthy and Dael Wolfle, "Doctorates Granted to Women and Minority Group Members", *Science*, Vol. 189 (1975), pp. 856-859.

[37] *Characteristics of Doctoral Scientists and Engineers in the United States, 1975*, National Science Foundation, (NSF 77-309), p. 61.

5-28. Women as a percent of all enrollments for advanced degrees by field, 1966, 1974 and 1975

Field	Women as a percent of total 1966	1974	1975
All science and engineering fields	13	22	24
Social sciences	24	35	37
Life sciences	20	26	28
Mathematical sciences	18	24	29
Physical sciences	10	14	15
Engineering	1	4	5

starting salaries between men and women may be narrowing, and in some cases women are receiving higher beginning salaries than men. For example, women majoring in most engineering disciplines received slightly higher starting salary offers than men in 1975.[38]

Because of the relatively small number of women scientists and engineers, their rate of increase in the doctoral population, their lower median age, and the narrowing of the gap in starting salaries, the differential in average salaries paid men and women in science and engineering may be smaller in the future.

Racial minorities in science and engineering

About 4 percent of all scientists and engineers in 1974 (87,000) were members of selected minority groups. Asians accounted for 1.8 percent, Blacks were 1.6 percent, and other nonWhites (e.g., American Indians) the remainder (Figure 5-30).

The distribution of minority scientists and engineers across fields of science varied considerably. For all racial minorities together, 4 out of every 10 were in engineering fields. Almost 2 of every 10 were social scientists. Over one-half of the Asians were engineers, as were one-fourth of the Blacks. The social sciences accounted for almost one-third of the total number of Black scientists and engineers compared to only 6 percent of Asian scientists and engineers.[39]

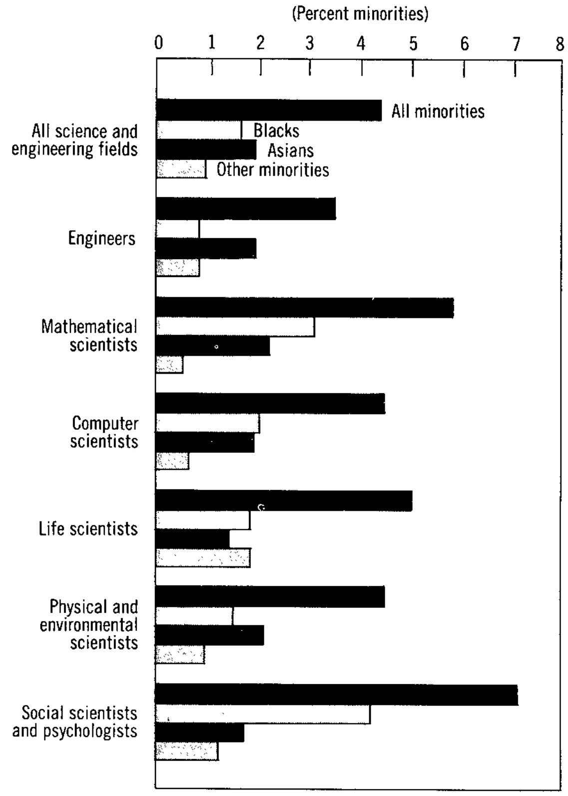
The representation of minorities among doctoral scientists and engineers in 1975 is shown in Table 5-31. Doctoral Blacks have only a slightly higher representation than all Black scientists and engineers, but Asian scientists and engineers are over twice as prevalent at the doctoral level than among all Asian scientists and engineers.

Among the Black doctoral scientists and engineers, in 1975 the largest proportion was involved primarily in teaching activities (40 percent), followed by management or administration (25 percent), and research and development (18 percent).[40] This general profile of activity applies in most of the fields. In 1975, Black doctoral scientists and engineers were employed for the most part by universities and 4-year colleges (62 percent), with the next largest proportions in industry (13 percent) and the Federal Government (8 percent)—a consistent pattern across most fields. In comparison, just over one-half of the White doctoral scientists and engineers were working in universities and 4-year colleges, with the next largest proportion (24 percent) employed by industry, and 7 percent working for the Federal Government.

Asian doctoral scientists and engineers exhibit quite different characteristics. They are primarily involved in research and development (51 percent), teaching (27 percent), and manage-

5-30

Minority representation among scientists and engineers by field, 1974



REFERENCE: Appendix Table 5-18.

[38] *CPC Salary Survey Final Report,* The College Placement Council, July 1975.

[39] *U.S. Scientists and Engineers: 1974,* National Science Foundation (NSF 76-329), pp. 24-25.

[40] *Characteristics of Doctoral Scientists and Engineers in the United States, 1975,* National Science Foundation, (NSF 77-309), pp. 48-49.

5-31. Minorities as a percent of all doctoral scientists and engineers by field, 1975

Field	Black	American Indian	Asian[1]
	Percent of each field		
All science and engineering fields	1.0	0.2	4.9
Physical scientists	1.0	(2)	5.1
Mathematical scientists	.7	(2)	5.0
Computer specialists	.9	(2)	5.2
Environmental scientists	.3	(2)	2.5
Engineers	.3	.1	9.6
Life scientists	1.1	.1	4.6
Psychologists	1.1	.2	.9
Social scientists	1.5	.3	3.4

[1] Excluding East Indians.
[2] Less than 0.5 percent.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1975* (NSF 77-309), pp. 35-37.

ment or administration (9 percent). Compared with the other minorities, a greater proportion of Asians are employed by industry: 50 percent in universities and 4-year colleges, 34 percent in industry, and 5 percent in the Federal Government.

These data suggest that there are characteristic patterns of involvement in science for the various minorities. Black doctoral scientists and engineers, for example, are found more often in the social science and health science fields, predominantly involved in teaching activities. In contrast, Asians tend to be in the physical sciences and engineering, with primary involvement in R&D activities.

An indication of the participation of minority students in science and engineering graduate study is presented in Table 5-32. It should be pointed out that these data do not represent national totals, but they were reported by a significant proportion of doctorate-granting institutions. The largest percentages of Black graduate students occurred in health professions and the social sciences in 1973, while engineering and the physical and life sciences attracted the lowest proportion of Black graduate students. For Asian graduate students, engineering and the physical sciences have the higher proportions of minority enrollments.

5-32. Minorities as a percent of all graduate enrollment in selected doctorate-granting institutions by field, 1973

Field	Black	Spanish-surnamed	American Indian	Asian American
	Percent of each field			
Total enrollment	4.4	1.1	0.3	1.4
All science and engineering fields	2.5	.9	.3	2.1
Physical sciences	1.4	.7	.2	2.6
Mathematical sciences	2.5	.6	..2	2.1
Engineering	1.2	.8	.1	3.3
Life sciences	1.5	.9	.2	1.9
Health professions	5.5	1.2	.6	2.0
Social sciences and psychology	4.1	1.2	.3	1.1
All nonscience fields	5.4	1.2	.4	.9

SOURCE: Elaine H. El-Khawas and Joan L. Kinzer, *Enrollment of Minority Graduate Students at Ph.D. Granting Institutions,* (Washington, D.C.: American Council on Education, 1974), based on pp. 13 and 17.

UNEMPLOYMENT AMONG SCIENTISTS AND ENGINEERS

Unemployment rates are only an imperfect expression of the supply/demand balance. The National employment rate, for example, is traditionally expressed in terms of occupation last held. In some cases an individual scientist or engineer may have taken a nonscience or nonengineering job before becoming unemployed and would therefore not be reported as an unemployed scientist or engineer. Unemployment levels, furthermore, do not indicate the degree of underutilization in positions requiring lesser skills than individuals actually possess. In addition, in most instances it is not possible to measure the difficulty or the length of time required for obtaining employment for scientists and engineers who are first entering the job market or for those who are changing jobs.

Historically, unemployment among scientists and engineers has been relatively low. During most of the 1960's, the unemployment rate for these workers ranged below 1 percent. This was below the rate for all professional and technical workers and substantially below the rate for all types of workers combined (Figure 5-33). In 1971, the unemployment rate for scientists and engineers reached a level around 3 percent, nearly as high as the unemployment rate for all professional and technical workers, but well below the 6 percent rate for all workers in the economy.[41] This change in the labor market for scientists and engineers resulted from a series of factors—cut-backs in defense spending, reductions in defense and other R&D programs, and the lessened demand for academic faculty. By 1972, however, the labor market for scientists and engineers began to improve. The unemployment rate for engineers, for example, dropped from 3.2 percent in the first quarter of 1971 to less than 1 percent at the end of 1973—comparable to the rates of the mid-1960's.

In 1976, the combined unemployment rate for a sample of scientists and engineers who were classified as such in the 1970 Federal Census was 1.9 percent.[42] Of those employed, 97 percent held full-time positions in 1974 while 3 percent were working part-time.

For 1976, the unemployment level for engineers alone was 1.7 percent, compared to a 1974 average of 1.3 percent (see Appendix Table 5-19).[43] Increases in engineering unemployment between 1974 and 1976 reflected the downturn in economic activity and the rise in the unemployment rate for all workers from 5.6 percent in 1974 to 7.7 percent in 1976. Similarly, the unemployment rate for professional, technical, and kindred workers advanced from 2.3 to 3.2 percent over the 2 years. The manufacturing sectors of the economy absorbed most of the initial decline in employment over the 1974-76 period, and many engineers are employed in these manufacturing industries. It should be noted that even while the unemployment of engineers rose from 1.3 to 1.7 percent from 1974 to 1976, over 20,000 additional positions for engineers were added to the labor market in this period.

The combined unemployment rate of 1974 and 1975 recipients of science and engineering bachelor's degrees was 13.0 percent in 1976—11.5 percent for the 1974 graduates and 14.6 percent for the 1975 graduates.[44] Engineers and computer scientists were best able to obtain employment in the field of their major subject of study—96 percent and 92 percent respectively. The most difficulty in 1976 was experienced by new physicists and economists, with only about 45 percent able to work in their own field. This may be due to the degree of occupational emphasis of these programs at the bachelor's degree level, as well as the job market for new scientists.

The unemployment rate for doctoral scientists and engineers was below 1 percent in 1975, the latest year for which data are available.

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[41] *Unemployment Rates and Employment Characteristics for Scientists and Engineers, 1971,* National Science Foundation (NSF 72-307), p. 61.

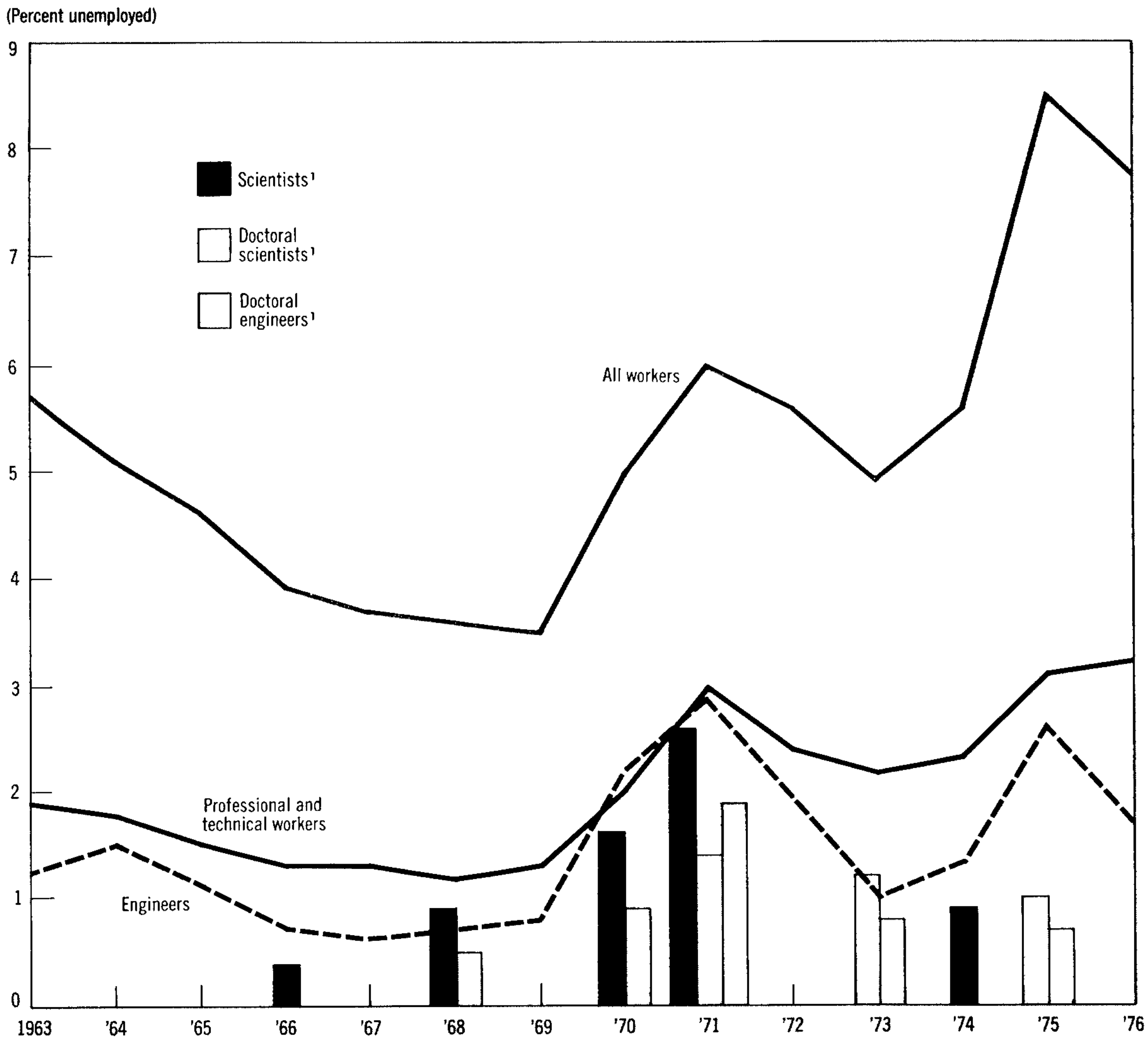
[42] "National Sample of Scientists and Engineers: Changes in Employment 1970-72 and 1972-74," *Science Resources Studies Highlights,* National Science Foundation (NSF 75-309), May 19, 1975, and unpublished data.

[43] The unemployment rate for engineers in the first quarter of 1977 is estimated at 1.5 percent.

[44] National Science Foundation, unpublished data.

5-33

Annual average unemployment rates, 1963-76



[1] Years for which three bars are not shown are the years for which these data are not available.

REFERENCE: Appendix Table 5-19.

ADDITIONS TO THE SUPPLY OF SCIENTISTS AND ENGINEERS

Interest of students in science and engineering

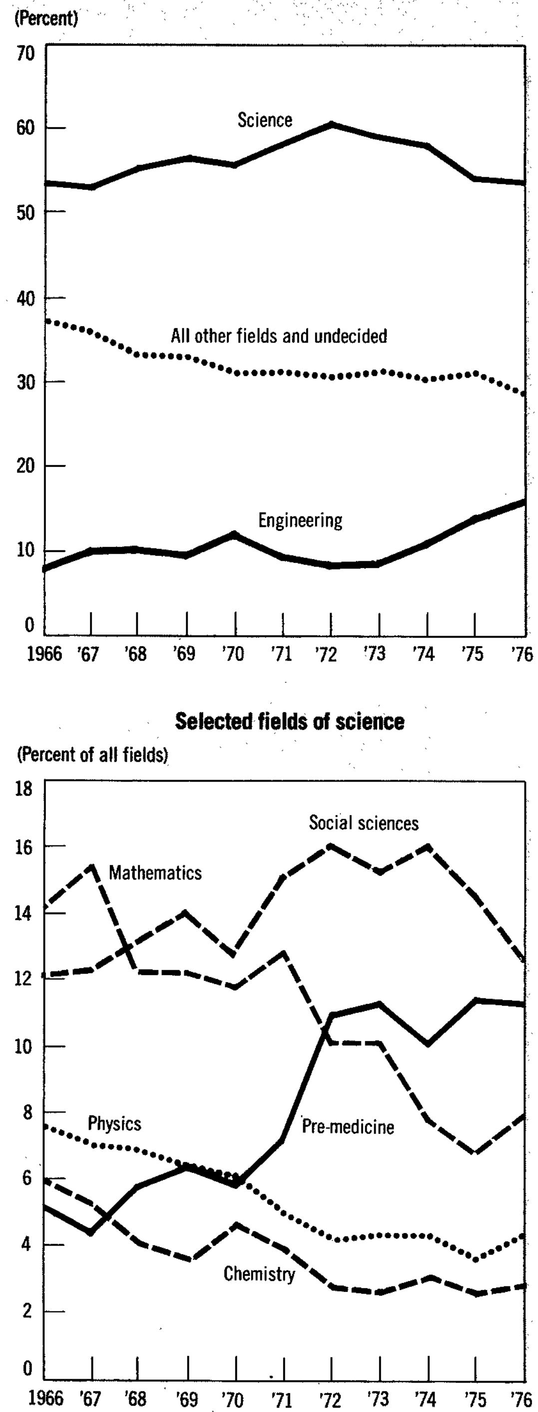
The choice of college majors by National Merit Scholars as they enter their junior year in high school provides an indicator of early interest of extremely capable students in science and engineering (Appendix Table 5-20). Between 1966 and 1976 the proportion of these students planning to enter science or engineering increased from 62 percent to 70 percent. The proportion of National Merit Scholars choosing science as a major declined by six percentage points between 1972 and 1976 (Figure 5-34), while over this same period there was an increase of eight percentage points for those planning to major in engineering; about half of this growth occurred between 1974 and 1976.

A second indicator of early student interest in science and engineering is provided by occupational preferences of college freshmen (Figure 5-35). Business fields have received the most occupational interest in recent years. Interest in becoming an engineer continues to increase after a 4-year plateau, returning to the 1970 level. Occupational interest in education as a career, which has decreased substantially in recent years, showed a slight upturn in 1976. At the same time, there was a downturn of interest in the non-M.D. health professions.

Undergraduate enrollment in major fields is generally first obtainable for junior-year students. The latest data from a national sample show that total junior-year undergraduate enrollment increased by 2 percent between fall 1973 and fall 1974[45] (Figure 5-36). However, the number of students majoring in science and engineering fields increased only 1.1 percent, which was not statistically significant. Computer and information sciences, and agriculture and natural resources majors increased by 9 percent. There were also more junior-year majors in the biological sciences. Decreases occurred in the number majoring in mathematics and social sciences and were important because these two latter groups accounted for almost half (48 percent) of all junior-year science and engineering majors.

[45] Irene L. Gomberg and Frank J. Atelsek, *Major Field Enrollment of Junior Year Students, 1973 and 1974*, (Washington, D.C.: American Council on Education, 1976), p. 6.

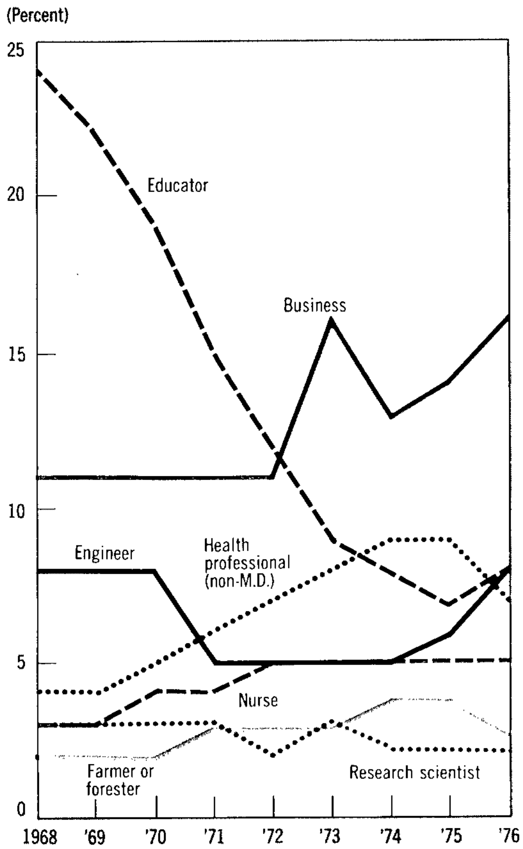
5-34
Fields of college major chosen by National Merit Scholars, 1966-76



REFERENCE: Appendix Table 5-20.

5-35

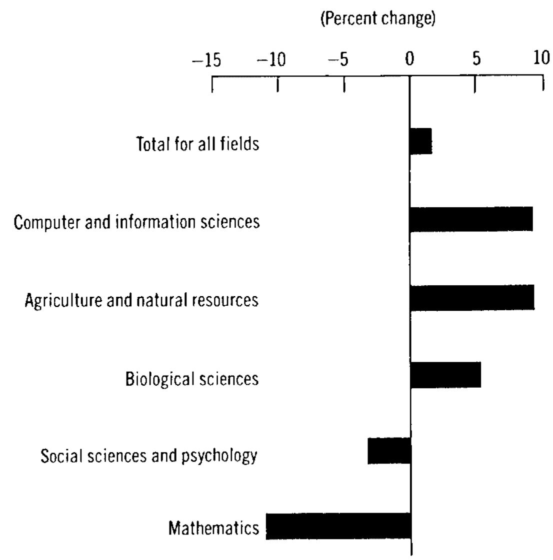
Percent distribution of selected occupational preferences of college freshmen, 1968-76



REFERENCE: Appendix Table 5-21.

5-36

Significant changes in enrollment of junior-year undergraduate students by selected major fields, 1973 to 1974



REFERENCE: Appendix Table 5-22.

Bachelor's and first-professional degrees awarded

Bachelor's and first-professional degrees[46] awarded for the years 1960 through 1975 are shown in Figure 5-37. In 1975, the number of degrees granted in all fields combined, and in science and engineering, declined for the first year since 1955. Social science degrees[47]—as a proportion of all bachelor's degrees in science and engineering—rose from about 26 percent of the total in 1960 to almost half (47 percent) in 1975.

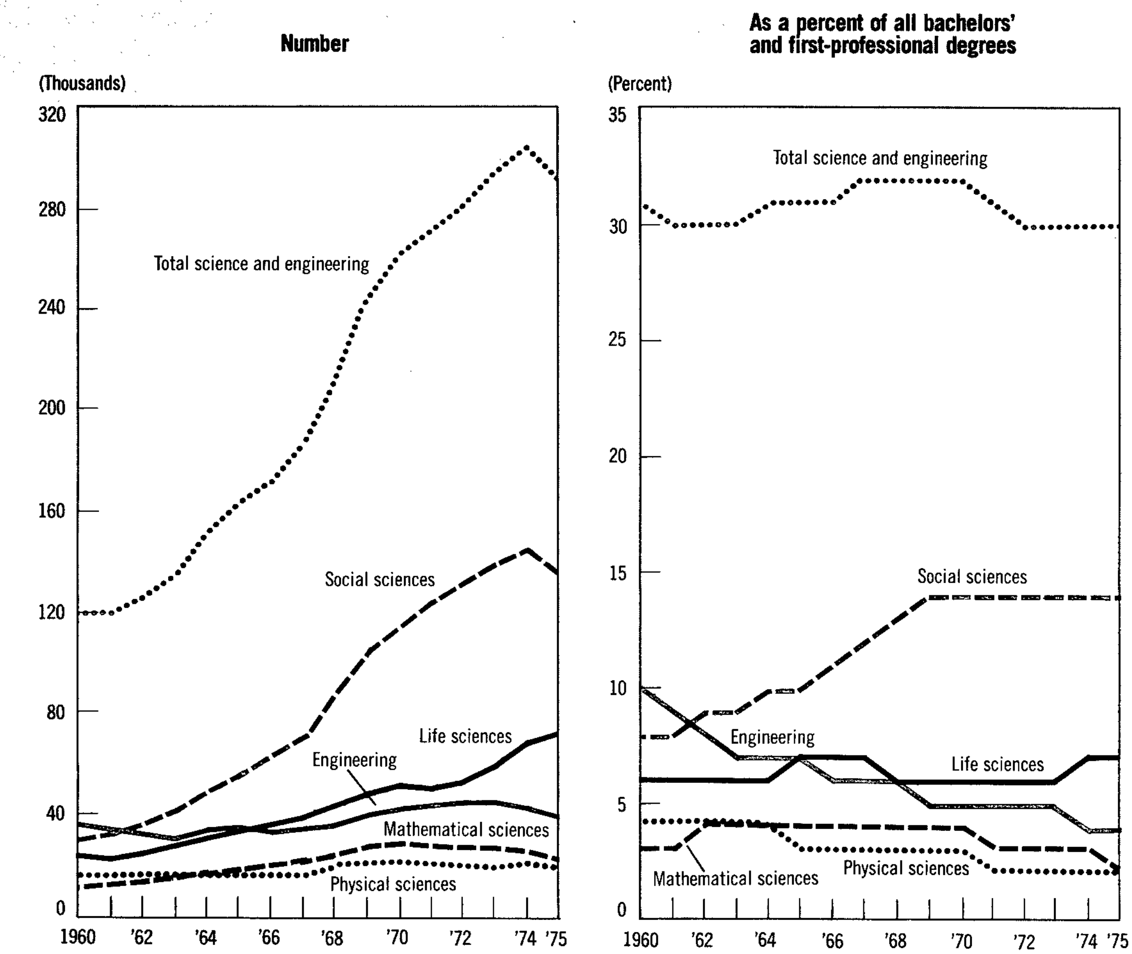
Between 1960 and 1975, bachelor's degrees in science and engineering, as a fraction of all bachelor's and first-professional degrees in all fields, remained essentially constant at approximately 30 percent. The large annual increases in social science degrees at this level were responsible for maintaining this proportion. Engineering degrees declined consistently from 10 percent to 4 percent of these degrees in all fields during the period, while the physical sciences fell from 4 percent to 2 percent.

Enrollment for advanced degrees

During the past decade and a half, enrollment for post-baccalaureate degrees in all fields has reflected the complex influence of many factors, including population trends, changes in attitudes and aspirations (such as the increase in career interests among women), military draft regulations, employment outlook, altered expectations of the value of higher education, and financial resources available to students. Reductions in Federal support programs for graduate

[46] First-professional degrees include the M.D., D.D.S., D.V.M., and J.D. degrees.
[47] Including psychology.

5-37
Bachelor's degrees awarded in science and engineering by field, 1960-75



REFERENCE: Appendix Table 5-23.

students have had an obvious, though not precisely measurable, influence on enrollment for advanced degrees in science and engineering.

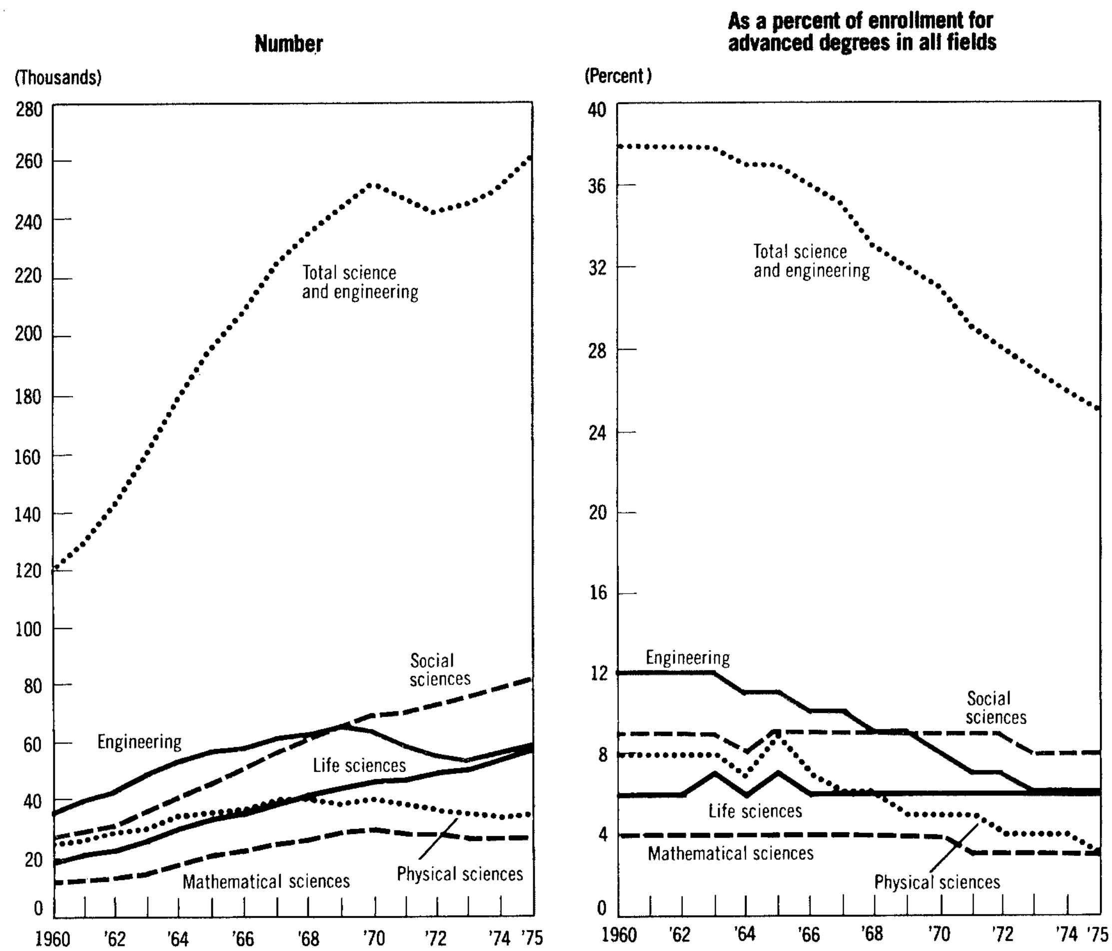
From 1960 to 1975 enrollment for advanced degrees in science and engineering more than doubled (Figure 5-38). Physical science enrollment peaked in 1968, engineering enrollment in 1969, mathematics in 1970, while the social and life sciences enrollments have continued to increase each year since 1960.

The direction of more recent trends in graduate enrollment may also be seen in additional data collected those institutions granting science and engineering doctorates. These data, although not strictly comparable to those above, indicate that full-time graduate science and engineering enrollment increased by nearly 10 percent over fall 1974, followed by a 2 percent increase from 1975 to 1976. The social and life sciences accounted for almost two-thirds of the overall increase.[48]

[48] By one standard deviation.

5-38

Enrollment for advanced degrees in science and engineering, 1960-75



REFERENCE: Appendix Table 5-24.

The most rapid growth in enrollment for advanced degrees during the 1960-75 period occurred in fields other than science and engineering. Consequently, enrollment for advanced degrees in science and engineering fields as a proportion of all advanced degree enrollment declined from 38 percent in 1960 to 25 percent in 1975 (Figure 5-38). The physical sciences and engineering accounted for most of this reduced share.

It has been suggested that this drop may be due to the most promising students electing to pursue nonscience fields. However, a recent study of the aptitude scores of graduate school applicants does not support this claim.[49] From 1970-71 to 1974-75, there were no changes of practical significance in average aptitude of all applicants. The major differences were those between fields, occurring consistently over the

[49] *Graduate Science Education: Student Support and Postdoctorals, Fall 1974*, National Science Foundation (NSF 76-313) and *Graduate Science Education: Student Support and Postdoctorals, Fall 1975*, Detailed Statistical Tables, National Science Foundation (NSF 76-318), p. 199.

entire period studied. In quantitative ability, candidates for graduate study in the sciences and engineering averaged much higher[50] than those wishing to enter nonscience fields, and within the sciences, the physical and mathematical science candidates averaged much higher than those in the life and social sciences. In verbal ability, the science and engineering and the nonscience candidates did not differ on the average, but within the science and engineering group, engineering candidates averaged noticeably lower than the others.

Graduate student support

Patterns of Federal support of fellowships, traineeships, and training grants have changed markedly in recent years. There has been a tendency toward participation in federally funded research projects in areas of national concern in place of direct student aid. Federal obligations specifically for fellowships, traineeships, and training grants declined from $421 million in 1971 to $287 million in 1973.[51] These funds then rose in 1974 to $327 million, largely because approximately $60 million of funds impounded in 1973 were released to the Department of Health, Education, and Welfare. Total agency obligations for these purposes then declined to $201 million in 1975, the lowest point since these data have been available. In constant 1972 dollars, this represents a 64 percent reduction. The HEW total, which fell from $301 million in 1974 to $182 million in 1975, accounted for most of this decline.

The U.S. Office of Education's student programs under the now terminated National Defense Education Act, those of NSF and NASA, were among the Federal agency activities affected by the shifts in funding. Current dollar obligations by the Office of Education declined from $52 million in 1971 to $41 million in 1972, and after the expiration of National Defense Education Act awards, to $10 million in 1973. In 1974 and 1975 the Office of Education obligated only a little over $1 million to these programs. NSF's support of fellowships and traineeships dropped from $42 million in 1971 to $10 million in 1975, and NASA's traineeships have been virtually eliminated, amounting to only a total of about $1 million in 1973, 1974, and 1975.

All fields of science were affected by the reductions in Federal support of fellowships, traineeships, and training grants. The largest absolute decrease occurred in the life sciences, which dropped from $225 million in 1971 to $179 million in 1973. The release of the impounded 1973 HEW funds brought the 1974 total for the life sciences back up to $226 million. In 1975, however, the amount declined again to $136 million, reaching the lowest level since separate data were first collected in 1971.

Master's degrees awarded

Master's degrees awarded annually for the 1960-75 period are shown in Figure 5-39. The number of degrees conferred in all fields increased in each year through 1975. However, the total number of master's degrees awarded in science and engineering reached a peak in 1973. Degrees in the physical sciences reached their maximum even earlier, in 1971; those in engineering and mathematical sciences dropped after 1972, while degrees in the life and social sciences continued to increase each year. As a fraction of master's degrees in all fields, science and engineering degrees declined from a high of 30 percent in 1965 to only 18 percent in 1975; the greatest proportional declines occurred in engineering and the physical sciences.

It should be noted that many students enrolled in doctorate programs in which no masters degree is awarded reach the same level of competence as those reported as receiving master's degrees along the way to the doctorate or as a terminal degree. This policy variation affects similar fields at different institutions as well as different departments of the same institution.

Doctoral degrees awarded

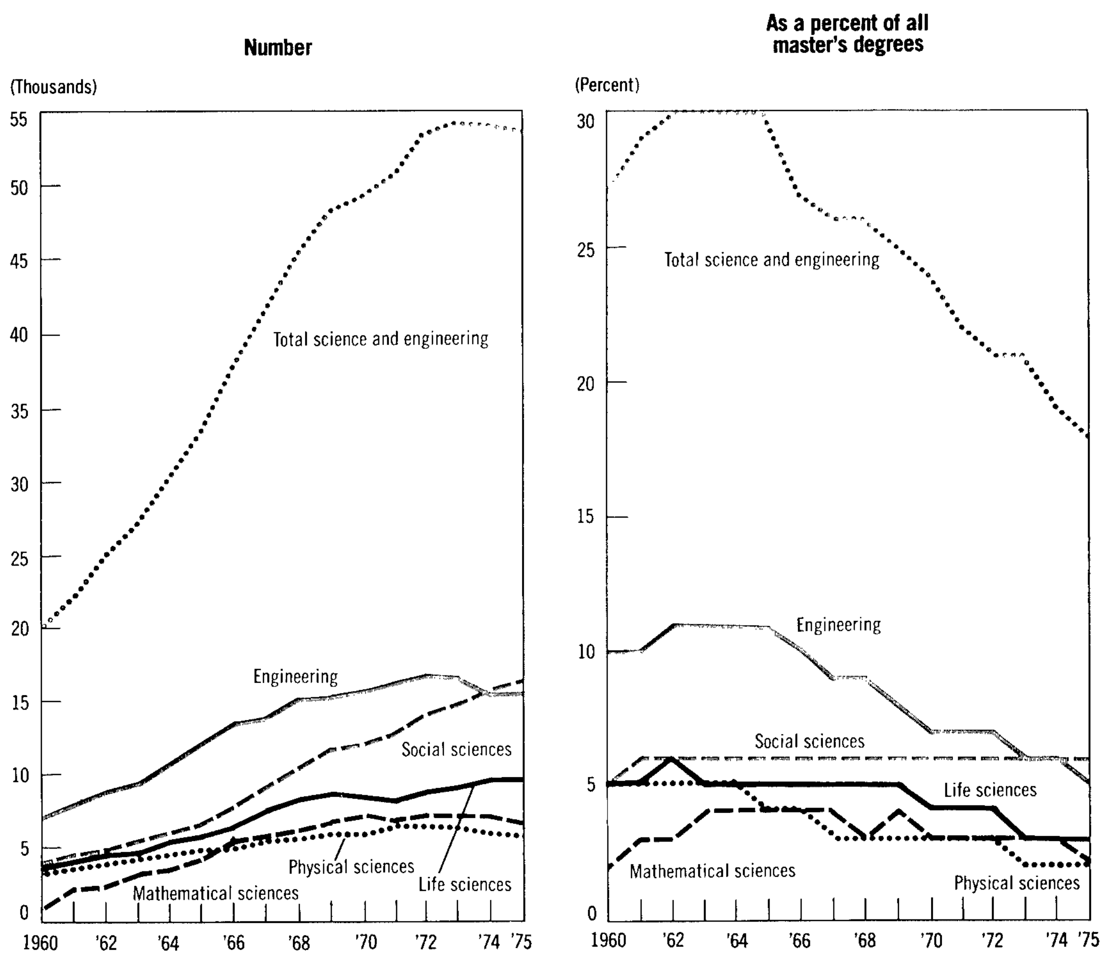
The number of doctorates awarded in each year of the 1965-76 period is shown in Figure 5-40. The numbers of doctoral degrees earned in all fields combined and in science and engineering combined reached their peaks in 1973. The number of science and engineering degrees awarded each year has ranged between 17,800 and 19,000 in the 1970-76 period. The majority of all doctorates awarded between 1965 and 1976 were in science and engineering fields, but

[50] *Trends in Aptitude of Graduate Students in Science* (Princeton, J.J.: Educational Testing Service, 1976).

[51] *Federal Support to Universities, Colleges, and Selected Nonprofit Institutions*, National Science Foundation, annual series.

5-39

Master's degrees awarded in science and engineering, 1960-75



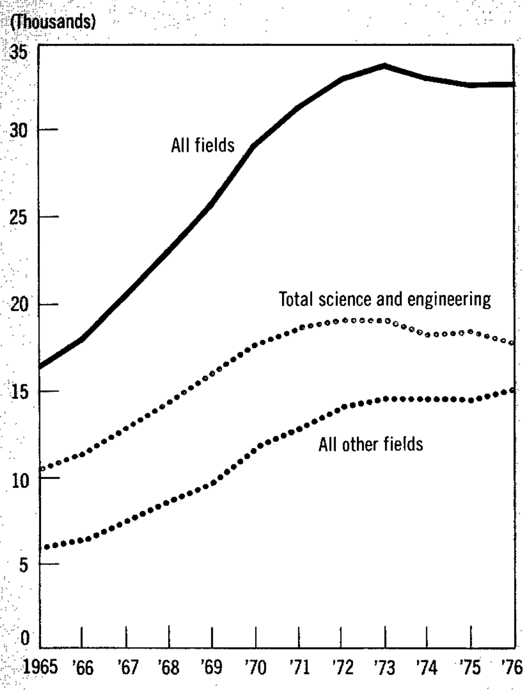
REFERENCE: Appendix Table 5-25.

their share fell from a high of 64 percent in 1965 to a level of 54 percent for the 1973-76 period. The number of men receiving doctoral degrees in science and engineering decreased in 1974, 1975 and again in 1976, and although there were increases in women doctorate recipients, they were not sufficient to offset the drop for men.

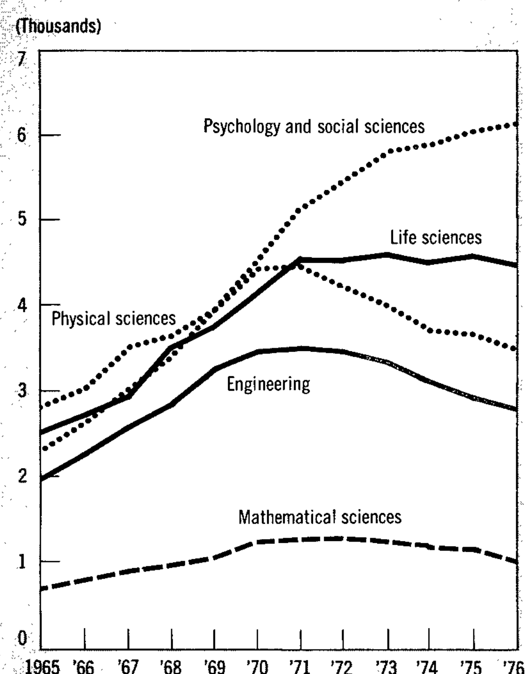
Trends in doctorates awarded in individual major areas of science and engineering over the 1965-76 period are also shown in Figure 5-40.

The physical sciences and engineering exhibited the largest decline in recent years; the number of physical science doctorates awarded dropped 73 percent from 1971 to 1976. This decline in annual awards in the physical sciences is due largely to the sharp drop in physics and astronomy doctorate recipients—down 29 percent from 1971 through 1976—and to a 26 percent decrease in chemistry doctorates conferred over the same period. In contrast, the number of social science doctorates rose 19 percent from 1971 to 1976.

5-40
Doctoral degrees awarded, 1965-76



Science and engineering doctorates by field, 1965-76



REFERENCE: Appendix Table 5-26.

Immigrant scientists and engineers

Additions to the U.S. supply of scientists and engineers also result from persons immigrating from other countries. About 7,000 scientists and engineers immigrated officially to the United States in 1975,[52] of whom some 2,500 had already been in the country on temporary visas. The rest came on a temporary basis as exchange visitors, industrial trainees or transferees of multinational companies. Over the 1966-75 period about 100,000 scientists and engineers permanently immigrated to the United States, almost 40 percent of whom had come here originally on temporary visas, and subsequently achieved formal immigrant status.

Although since 1973 the number of permanent immigrant scientists and engineers entering each year has fallen to almost half the level of the peak years of the late sixties, the total number of all foreign scientists and engineers entering from 1973 to 1975 has not fallen as sharply, due to the increased inflow of nonimmigrant, foreign scientists and engineers in the later period. Table 5-41 summarizes the scientist and engineer inflow patterns of the past decade.

In 1975, foreign doctoral scientists and engineers made up 6 percent of all doctoral scientists and engineers,[53] ranging from lows of 2 percent of the psychologists and 4 percent of the agricultural scientists and of the sociologists, to highs of 10 percent of the atmospheric scientists and 8 percent of the engineers and of the physicists/astronomers.

One-half of the foreign doctoral scientists and engineers were life scientists or physical scientists (25 percent each), while 23 percent were engineers, 14 percent social scientists or psychologists, and 6 percent mathematical scientists. This distribution generally follows the field distribution of doctoral scientists and engineers who are U.S. citizens.

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[52] "Scientists and Engineers from Abroad: Trends of the Past Decade, 1966-75," *Review of Data on Science Resources*, National Science Foundation (NSF 77-305).

[53] Based on *Characteristics of Doctoral Scientists and Engineers in the United States, 1975*, National Science Foundation (NSF 77-309), p. 34.

5-41. Average annual inflow of foreign scientists and engineers, 1966-75
(In thousands)

Period	Total foreign scientists	Imigrants			Non-immigrants[1]
		Total	Direct immigrants	Change of status	
1966-75	15.0	10.0	6.2	3.9	5.0
1966-72	16.4	11.5	7.0	4.5	4.8
1973-75	12.0	6.5	4.2	2.3	5.5

[1] Data are lacking on foreign science and engineering students who enter the United States on nonimmigrant student visas. Some of these students later become immigrant scientists and engineers, but they are excluded from the data in this table.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, "Scientists and Engineers from Abroad: Trends of the Past Decade, 1966-75," *Review of Data on Science Resources* (NSF 77-305), February 1977.

Chapter 6
Public Attitudes Toward Science and Technology

Public Attitudes Toward Science and Technology

INDICATOR HIGHLIGHTS

- In the public's rankings of ten occupations according to prestige, scientists were second only to physicians in 1972, 1974, and 1976, with engineers in third place. This is in spite of a general decline in the public's regard for the ten occupations from the 1960's to the 1970's and again from 1974 to 1976. The relative standing of scientists has improved since the 1960's.
- While the public in general has a high regard for science and scientists, this regard is highest among the relatively affluent and educated and those who have professional or managerial occupations. The least favorable attitudes are held by the poor and uneducated, and those who live and work on farms. These latter groups also respond "no opinion" with high frequency.
- About 70 percent of the public believed in 1972 and 1976 that science and technology have changed life for the better, and over half believed that they have done more good than harm. More favorable attitudes on these issues were expressed in 1974 than in either 1972 or 1976.
- Improvements in medicine are by far the greatest benefit that the public believes science and technology have produced, followed by space exploration. The most harmful thing is damage to the environment, with the expense and dangers of the space program coming second.
- In 1976, 6 percent of the public thought that science and technology have caused most of our problems, 45 percent some of our problems, 28 percent few of our problems, and 14 percent none of our problems. In 1972, only 9 percent felt that none of our problems were caused by science and technology. Government decisionmakers were most often cited in 1976 as the group responsible for causing such problems, while business decisionmakers too were often mentioned. Scientists and engineers were very seldom cited, but there was a marginally greater concern about engineers. There was also a marginally greater desire to control technology than science, especially among professionals and the college educated.
- The portion of the public that believed that science and technology will eventually solve most problems such as pollution, disease, drug abuse, and crime was 27 percent in 1976. This number had been 30 percent in 1972 and had dropped to 23 percent in 1974.
- The two problem areas in which science and technology would be most effective, in the view of the public, are health care and pollution. The two areas in which they would be least effective are thought to be reducing crime, and weather control and prediction.
- The areas in which the public would *most* like its tax money spent for science and technology are the same as those in which they are considered potentially most effective. The areas in which the public would *least* like its money spent are space exploration, defense, birth control, and weather control and prediction.

An essential aspect of the scientific enterprise in the United States is the attitudes of the U.S. public toward that enterprise. Those attitudes affect science and technology in many ways. Directly, public attitudes influence the decision of young people to take up careers in science-related fields. Also, they affect public voting in areas related to technology. Indirectly, public attitudes influence the scientific enterprise through their influence on the actions of government at all levels. These actions take the form of decisions to fund or to regulate certain research or technological activities. The 1976 report of the National Science Board, *Science at the Bicentennial: A Report from the Research Community,* showed that the scientific community in the United States is greatly concerned about public attitudes toward science and technology, because it perceives a deterioration in these attitudes to be the cause of many of its current problems.

The survey of public attitudes summarized in *Science Indicators—1972* and *Science Indicators—1974* was repeated for this report,[1] with a few modifications that will be discussed below. Personal interviews were conducted in September 1976 with 2,108 persons 18 years of age or older. The sampling method used in the survey permits the results to be projected to the entire U.S. adult population.

Such public opinion surveys provide information that cannot be gained in any other way. However, their limitations should also be recognized. The wording and ordering of questions may have an unexpected effect on the response obtained. A respondent may really have no opinion on a particular issue, or may confuse one issue with another, so that his response does not reflect his actual opinion. Further developments in polling technique are expected to minimize such effects. Finally, it must be understood that the purpose of this survey was to elicit *opinions,* rather than information, about science and technology. Some respondents may be misinformed or uninformed, for example, as to what effects science and technology have had on society and what they are able to accomplish. Even so, it is valuable to know what they believe about these things. Indeed, it may be especially important to know when the public has unrealistic beliefs or expectations about science and technology.

In this chapter, the public attitudes revealed by the survey are grouped for discussion into four sections: general attitudes, results of science and technology, capabilities of science and technology, and public preferences. In each case, the attitudes expressed by the total public are shown, as well as the attitudes of those demographic groups that diverged most significantly from the total public. The 1976 results are compared with those from 1972 and also with the 1974 results when the latter show a significant difference from both 1972 and 1976. Comparison is also made with the results of other surveys in which similar questions were asked.

GENERAL ATTITUDES TOWARD SCIENCE AND TECHNOLOGY AND TOWARD THEIR PRACTITIONERS

The public continues to have an overwhelmingly positive general reaction to science and technology. Out of four possible evaluations of science and technology, over 70 percent of the public chose favorable replies in both 1972 and 1976.

6-1. General reactions to science and technology

Reaction	Percent 1972	Percent 1976
Excitement or wonder	23	23
Satisfaction or hope	49	55
Fear or alarm	6	6
Indifference or lack of interest	6	9
No opinion	16	7

SOURCE: Opinion Research Corporation, *Attitudes of the U.S. Public Toward Science and Technology, Study III* (September 1976), p. 16.

The reaction "excitement or wonder" was expressed by 23 percent of the public in both years. In 1976, this response was given more often by people between 18 and 29 years of age,

[1] These three surveys were conducted by Opinion Research Corporation, Princeton, N.J. For more information on the survey method and results, including statistical significance levels and complete demographic breakdowns, see their publication *Attitudes of the U.S. Public Toward Science and Technology, Study III* (September 1976). This study was commissioned specifically for the present report. It and the ORC reports of the 1972 and 1974 surveys (Study I and Study II) can be ordered from the National Technical Information Service, U.S. Department of Commerce.

by those with some college, those with "professional" occupations and those with annual incomes over $15,000. Fewer people with incomes under $5,000 or 60 years old or over had this reaction.

The most common reaction was "satisfaction or hope", at 55 percent in 1976, which was significantly above the 49 percent with this reaction in 1972. Again persons with annual incomes below $5,000 had this feeling less often than the average—less often, in fact, than any other group.

"Fear or alarm" was the reaction of 6 percent in both years. This was the least frequent response in 1976. However, the group with incomes under $5,000 expressed this reaction 12 percent of the time.

Besides their attitude toward science and technology as such, one may ask about the public's attitude toward the persons who practice them. Table 6-2 below is concerned with the attitudes of the public toward scientists and engineers, as compared with other professionals. Each job or profession listed was rated as "excellent", "good", "average", "below average", or "poor" in terms of its prestige or general standing. The table shows the percent answering "excellent" or "good" for each occupation in each of the years in which this survey has been taken. The occupations are rank-ordered according to the proportion of "excellent" or "good" ratings they were given in 1976.

6-2. Prestige of occupations

Occupation	Percents responding "excellent" or "good" for each occupation		
	1972	1974	1976
Physician	92	91	86
Scientist	86	89	81
Engineer	83	86	77
Minister	80	80	75
Architect	82	85	74
Banker	80	76	72
Lawyer	80	78	69
Accountant for a large business	75	76	67
Businessman	72	71	61
U.S. representative in Congress	73	65	52

SOURCE: Opinion Research Corporation, *op. cit.*, pp. 5-14.

The public's esteem for scientists in 1976 was second only to its esteem for physicians, among the ten occupations listed. The same was true in 1972 and 1974. Engineers ranked third, directly after scientists, in each year. The table also shows that there has been a general drop in the public's regard for all ten occupations, between 1972 and 1976. The drop was especially severe in the case of lawyers and businessmen, and most severe in the case of U.S. representatives in Congress, who ranked lowest of these ten occupations in each year.[2] In most cases, the drop from 1974 to 1976 was greater than the drop, if any, from 1972 to 1974. However, in spite of the general decline in prestige for all jobs, scientists and engineers maintained their relative standing.

In 1976, those who most often responded "excellent" or "good" with regard to scientists were in one of the following groups: those from 30 to 49 years of age; those who had some college education; had professional, managerial, or clerical or sales occupations; lived in cities of over one million population or in the northeastern United States; or had incomes of $15,000 or more per year. Those with the least favorable attitudes were 60 years old or more, had not completed high school, worked on farms, lived in the South, or had annual incomes below $5,000.

In the case of engineers, those giving them an especially high general standing in 1976 belonged to the managerial occupations. Those giving them an especially low general standing were 60 years old or more, had less than a high school education, lived in rural areas, or had incomes below $5,000 per year.

There have been many other studies of public attitudes toward professions, including science, with which these results can be compared. Similar (though not identical) surveys taken in 1947 and 1963 found the following ratings for occupations on the previous list:

[2] The 1976 survey was taken in September. In April 1977, the Gallup Poll reported that 36 percent of the American public approves of the way the U.S. Congress is handling its job. (*The Gallup Poll*, Release of April 14, 1977.) This is more favorable than the September 1976 result and may suggest a recent improvement in the public's view of Congress.

6-3. Prestige of occupations

Occupation	Percents responding "excellent" or "good" for each occupation	
	1947	1963
Physician	97	96
Scientist	91	95
Civil engineer	88	92
Minister	87	86
Architect	90	92
Banker	92	90
Lawyer	89	91
Accountant for a large business	82	82
U.S. representative in Congress	92	91

SOURCE: R. W. Hodge, P. M. Siegel, and P. H. Rossi, "Occupational Prestige in the United States, 1925-63", *American Journal of Sociology*, Vol. 70 (1964), pp. 286-302.

These were among the 30 highest-ranking occupations in a list of 90. In place of "engineer", this table has "civil engineer", while it has no entry corresponding to "businessman" on the previous table.

If differences in sampling method between the surveys are neglected, it would appear that there has also been a drop in the general standing of most occupations since 1947 and 1963. In any case, physicians again led the list in both years. The numerical ratings are closely bunched together, but by 1963 physicians and scientists had established a higher general standing than the other professionals listed. This pattern was to continue in the 1970's.

Since 1966, the Harris Survey and the National Opinion Research Center (NORC) have also measured the public's feelings toward scientists, using a somewhat different question. Some social institutions in this country are named, and the respondent is asked whether he or she has "a great deal" of confidence, "only some" confidence, or "hardly any" confidence in the *people running* each institution. Clearly this is not the same as asking for attitudes toward occupational groups as such, as in Table 6-2. The responses may reflect attitudes toward authority and institutions, as well as attitudes toward the occupations. Still, the trends in these responses over time may help in interpreting the response on Tables 6-2 and 6-3. In particular, the responses may help in evaluating the consistent drop in the expressed confidence in all occupations that is shown on those tables.

The Harris surveys were conducted in 1966, 1971, and 1972. Table 6-4 shows the results. The words in parentheses are names of occupations, taken from Table 6-2, that correspond to the institutions named in this survey. Similarly, results from NORC surveys conducted in 1973, 1974, and 1976 are shown in Table 6-5.

6-4. Confidence in people who run institutions

Institution	Percents responding "a great deal" of confidence, for each institution		
	1966	1971	1972
Medicine (physician)[1]	72	61	48
Banks and financial institutions (banker)	67	36	39
Scientific community (scientist)	56	32	37
Military	62	27	35
Education	61	37	33
Mental health and psychiatry	51	35	31
Organized religion (minister)	41	27	30
Retail business (businessman)	48	24	28
U.S. Supreme Court	51	23	28
Executive branch of the Federal Government	41	23	27
Major companies (businessman)	55	27	27
Congress (U.S. representative in Congress)	42	19	21
Press	29	18	18
Television	25	22	17
Organized labor	22	14	15
Advertising	21	13	12

[1] Terms in parentheses are the corresponding occupations, taken from Table 6-2.

SOURCE: *The Harris Survey*, Release of November 13, 1972.

6-5. Confidence in people who run institutions

Institution	Percents responding "a great deal" of confidence, for each institution		
	1973	1974	1976
Medicine (physician)[1]	54	60	54
Scientific community (scientist)	37	45	43
Banks and financial institutions (banker)	(2)	(2)	39
Military	32	40	39
Education	37	49	37
U.S. Supreme Court	31	33	35
Organized religion (minister)	35	44	30
Press	23	26	28
Major companies (businessman)	29	31	22
Television	18	23	19
Congress (U.S. representative in Congress)	23	17	14
Executive branch of the Federal Government	29	14	13
Organized labor	15	18	11

[1] Terms in parentheses are the corresponding occupations, taken from Table 6-2.
[2] Not included in 1973 and 1974 surveys.

SOURCE: National Opinion Research Center, University of Chicago, *Codebooks of the Spring 1973, 1974, and 1976 General Social Survey*, Question 78 in 1973, 87 in 1974, and 74 in 1976.

According to Table 6-4, there was a definite decline in public confidence in the people running all the listed institutions, from 1966 to the 1970's. Tables 6-2 and 6-3 make a similar point regarding the prestige of occupations. The scientific community shared in this trend. Table 6-5 shows a widespread increase in the public's confidence in the leaders of institutions from 1973 to 1974, followed by a decrease from 1974 to 1976. This applies to the scientific community in particular, though the 1974-76 change is too small to be considered significant.

Table 6-5 indicates a drop in public confidence from 1974 to 1976 in all the institutional leaders that correspond to occupations listed on Table 6-2. This suggests that the 1974-76 drop that Table 6-2 shows represents a genuine change in public opinion. Another possible explanation for the drop shown on Table 6-2 is that in 1976 for the first time the survey questionnaire was prefaced by a statement notifying the respondent that the questions to follow come from a Federal agency. This was done to comply with the Privacy Act of 1974. In view of the unfavorable attitudes expressed toward government in some of the 1976 responses, it is possible that this preface led to relatively negative answers to this question, which was the first one after the preface.

Tables 6-4 and 6-5 together provide a time series, extending from 1966 to 1976, measuring the public's confidence in the leaders of institutions. Since the tables come from two different sources, however, caution is needed when making comparisons between them.[3] It is relatively safe to compare rank orders on the two tables. Thus in 1966 scientific leaders ranked fifth among the institutions on Table 6-4, barely above leaders of major companies, who were sixth. In 1971 they were again fifth, though only slightly below banking leaders, who were third. In subsequent years, they gradually emerged in second place, next to medical leaders. By this measure, the leaders of the scientific community have gained in public esteem from 1966 to 1976, in relation to leaders of other institutions, in spite of a general drop in public confidence in all leaders of institutions.

Tables 6-2 and 6-3 show scientists ranking second only to physicians in every year indicated from 1963 to 1976. However, these lists do not contain some of the highly ranked institutions

[3] Both organizations have used this question annually from 1973 through 1976, with varying lists of institutions. Discrepancies between their results are greater than chance would account for.

on Tables 6-4 and 6-5 that made the scientific leaders rank slightly lower in some years.

RESULTS OF SCIENCE AND TECHNOLOGY

Besides asking about general attitudes, one can measure more specifically the public's feelings about the effects or results of science and technology. Have they made life better or worse, for the most part? What specific good or bad things have they done? Public attitudes regarding past and present effects of science and technology are discussed in this section. Table 6-6 shows that the vast majority of Americans feel that science and technology have made life better.

6-6. Have science and technology changed life for the *better* or for the *worse?*

Response	Percent 1972	1974	1976
Better	70	75	71
Worse	8	5	7
Both	11	11	12
Neither/no effect	2	3	3
No opinion	9	6	7

SOURCE: Opinion Research Corporation, *op. cit.*, p. 18.

The answers other than "better" or "worse" were volunteered by the respondents. The table shows that the response "better" was given by a large majority. The percent giving this reply rose in 1974 and returned nearly to its 1972 level in 1976. Again, the least favorable replies were given by those least privileged in U.S. society, particularly by those with lowest incomes, non-Whites, the oldest, and the least educated.

The Harris Survey also attempted to measure public attitudes on this issue in 1972, using a national sample of 1,548 households.[4] When asked whether modern life is much better off due to the wonders that scientific progress has brought, 81 percent agreed, 10 percent disagreed, and 9 percent were not sure. The response shown on Table 6-6 for 1972 was not this favorable, perhaps because the Harris question was more positively worded.

[4] *The Harris Survey*, Release of February 17, 1972.

A closely related issue is whether the public perceives that science and technology change life too fast or too slowly. Table 6-7 shows its reaction on this issue.

6-7. Do science and technology change things too *fast*, too *slowly*, or just about right?

Response	Percent 1972	1976
Too fast	22	23
Too slowly	16	16
Just about right	51	53
No opinion	11	8

SOURCE: Opinion Research Corporation, *op. cit.*, p. 17.

In both years, about half of the public was satisfied with the rate of change due to science and technology. Only 22 and 23 percent felt the pace was too fast. In 1976, significantly more men than women felt that science is changing things too fast (25 percent *versus* 20 percent). Those responding "too slowly" would presumably have liked to see even more work done in science and technology or even more of an effect of that work on society.

Other studies have also measured the public's feelings about the rate of change caused by science. For example, when asked whether they thought that science makes our way of life change too fast, 43 percent agreed in 1957, 47 percent in 1958, and 57 percent in 1964.[5] When asked in 1968 whether scientific research is causing the world to change too fast, 20 percent agreed strongly and 34 percent agreed somewhat, for a total of 54 percent.[6] These results suggest an increasing apprehensiveness about science in the interval from 1957 to 1968. Unfortunately, the question used in the present survey is sufficiently different that no direct comparison can be made.

There is broad agreement with the general proposition that science and technology do more good than harm, as Table 6-8 shows.

[5] A. Etzioni and C. Nunn, "The Public Appreciation of Science in Contemporary America", *Daedalus* (Summer 1974), pp. 192f.

[6] National Opinion Research Center, Study SRS-4050 (April 1968), Supplement for Question 61.

6-8. Overall, do science and technology do more *good* than harm, more *harm* than good, or *about the same* of each?

Response	Percent 1972	1974	1976
More good	54	57	52
More harm	4	2	4
About the same	31	31	37
No opinion	11	10	7

SOURCE: Opinion Research Corporation, *op. cit.*, p. 21.

A high percentage feel they do "more good," just as most people feel that science has changed life for the better. Moreover, there was an increase in those with this feeling in 1974, followed by a drop in 1976, just as on Table 6-6. In this case, however, a neutral response "about the same" was offered, and many took advantage of it. Again, in 1976 the reactions most favorable to science and technology were given by those between 30 and 39 years old, those with some college education, those with professional or managerial occupations, and those with higher incomes. The least favorable reactions came from those who had not completed high school, those with manual or service occupations, those with the lowest income, those who rent rather than own their homes, and non-Whites.

Louis Harris also investigated attitudes on this issue in 1972. When asked whether scientific discoveries have produced more good or more harm, an overwhelming 78 percent said more good, versus 9 percent who said more harm.[7] This is roughly similar to the responses on Table 6-8, if one recognizes that the Harris question did not offer the response "about the same" to the respondents. It is also comparable to the responses on Table 6-6 for 1972.

Those who felt that science and technology do more good than harm were asked to mention some "good thing" they thought science and technology had done. Then they were asked, in a second question, to name another good thing. The responses were then analyzed by classifying them under a set of appropriate headings. The combined results from the two questions are shown in Table 6-9.

[7] *The Harris Survey*, Release of February 17, 1972.

6-9. Benefits from science and technology

(Cited by those feeling they do more good than harm)

Benefit	Percent citing[1] 1972	1976
Improvements in medicine	79	81
Space exploration	26	24
General improvements (products and living conditions in general)	12	14
Protecting environment, conservation	12	11
Electrical and electronic products	9	11
Improved methods of travel and transportation	9	9
Food and agriculture	9	7
Energy programs	2[2]	5
Improved communications	3	4
Other answers	16	9
Don't know	4	4

[1] Two responses were requested.
[2] Includes only atomic energy in 1972.

SOURCE: Opinion Research Corporation, *op. cit.*, pp. 23-33.

It is clear from the table that by far the greatest benefit that the public perceives coming from science and technology is in the field of medicine. This is consistent with the high ranking that was accorded to the medical profession on Table 6-2. "Space exploration" is a distant second, followed by a number of benefits reported not more than 12 or 14 percent of the time.

Those who felt that science and technology do the same amount of good as of harm were asked to name one good thing that science and technology have done, and also one harmful thing. The responses again were analyzed and classified. Tables 6-10 and 6-11 show the results.

In the case of the *good* things reported (Table 6-10), the benefits cited are much the same as those on Table 6-9. The great exception is that those who felt science and technology have done as much good as harm failed much more often to produce an example (13 percent on Table 6-10 *versus* 4 percent on Table 6-9, for 1976). When these people were asked to name a *harmful* thing (Table 6-11), even more were unable to give an example (23 percent in 1976). However, there was an evident concern about the environment and conservation. This concern seems to have increased between 1972 and 1976.

6-10. Benefits from science and technology

(Cited by those feeling they do as much good as harm)

Benefit	Percent citing 1972	1976
Improvements in medicine	50	56
Space exploration	9	10
General improvements (products and living conditions in general)	6	5
Protecting environment, conservation	6	4
Electrical and electronic products	3	4
Food and agriculture	3	2
Improved methods of travel and transportation	2	2
Other answers	5	5
Don't know	17	13

NOTE: Percentages may not add to 100 percent because of rounding.

SOURCE: Opinion Research Corporation, *op. cit.*, pp. 41-45.

6-11. Harmful effects of science and technology

(Cited by those feeling they do as much good as harm)

Harmful effect	Percent citing 1972	1976
Harm to environment; waste of fuel resources	29	35
Expense and dangers of space program	16	11
Nuclear bombs and radiation	9	8
Food additives	(1)	7
Dangerous medicines	2	5
Drug abuse	1	3
Unemployment and general personal problems	(1)	2
Other answers	16	7
None or don't know	27	23

[1] These categories were included in "Other answers" in 1972.

NOTE: Percentages may not add to 100 percent because of rounding.

SOURCE: Opinion Research Corporation, *op. cit.*, pp. 47-49.

Concern about the environment was especially strong in 1976 among those with a high school or some college education and those in managerial professions. It was least often expressed by those 60 or over and those who had never completed high school. Negative reactions to the space program dropped significantly from 16 percent of the public in 1972 to 11 percent in 1976. This reaction was most often expressed in 1976 by those who had not completed high school, and least often by those with some college and those in professional occupations.

Those who felt that science and technology do more harm than good were asked to name two harmful things they have done.[8] There were too few respondents in this case to produce meaningful quantitative results, but the greatest concern was expressed in connection with pollution and the space program. Personal problems caused by science and technology, such as anxiety and difficulty in keeping up with rapid change, were also prominent concerns.

The 1972 Harris survey mentioned earlier also sought to find out what benefits and harms the public believes science and technology have brought. When asked for the two or three biggest benefits they personally had obtained from scientific progress, and also the biggest problems, members of the public gave the replies shown on Tables 6-12 and 6-13.

6-12. Benefits from scientific progress

Benefit	Percent citing[1] (1972)
Medical research	34
Major appliances (TV, refrigerators, air conditioning)	22
Easier, more comfortable living	19
Utilities (electric power, gas, telephone)	18
Better transportation	14
Drugs (vaccines, penicillin, etc.)	11
Longer life span	8
Food preservatives, easier to prepare	5
Progress in space, gone to moon	5
Work on pollution	2
Birth control pills	1
Atomic energy	1
None	18

[1] Multiple responses were accepted.

SOURCE: *The Harris Survey*, Release of February 17, 1972.

[8] Opinion Research Corporation, *op. cit.*, pp. 34-39.

6-13. Problems created by science

Problem	Percent citing[1] (1972)
Air, water, environmental pollution	45
Space can create health problems	9
Threat of atomic bombs	7
Man's loss of inspiration, values	4
Too much automation	4
Food quality poor	3
Drugs, control of life and death by medicine	3
Cars go too fast	2
Overpopulation	2
Birth control pills unsafe	1
Insecticides used wrong way	1
None	34

[1] Multiple responses were accepted.

SOURCE: *The Harris Survey*, Release of February 17, 1972.

These results can be compared only roughly with the answers on Tables 6-9 through 6-11, since both the questions and the classification schemes for the answers were somewhat different. Still, it is clear that medical advances were the benefits cited most often in both surveys. Similarly, environmental pollution was the main harmful effect, according to both surveys, by a wide margin. It is also significant that in both surveys a high percentage of members of the public could not name any harmful effect of science.

With regard to problems, most Americans feel that science and technology have caused some or few of our problems, rather than most of them or none of them. This is demonstrated by Table 6-14.

6-14. Have science and technology caused *most* of our problems, *some* of our problems, *few* of our problems, or *none* of our problems?

Response	Percent citing	
	1972	1976
Most	7	6
Some	48	45
Few	27	28
None	9	14
No opinion	9	7

SOURCE: Opinion Research Corporation, *op. cit.*, p. 19.

There is a strong and significant increase from 1972 to 1976 in the proportion who feel none of our problems are due to science and technology, but little change in the number expressing the other reactions. Overall, this would appear to be a favorable trend in the public's attitude toward science and technology.

Different demographic groups have various reactions to this issue. In 1976, only 9 percent of those 18 to 29 years of age felt that none of our problems can be attributed to science and technology, which is relatively unfavorable when compared with the 14 percent of the total population who felt this way. Results were similar for those living in the West. Only 34 percent of those who had not completed high school felt that some problems are due to science and technology; since many in this group had no opinion, this may mean that this group as a whole is not well informed on this issue. On the other hand, of those who had completed some college, 56 percent blamed science for some problems, 8 percent for none, while 2 percent had no opinion. Similar figures occurred with those in professional occupations. Since it is fairly noncommittal to blame science for *some* problems, these figures may indicate a high level of awareness that there are current problems related to science and technology, but it need not indicate a positive rejection.

Those with the lowest incomes ($5,000 or less per year) blamed science for *some* problems less often than the average (37 percent). Fewer of these said *few* problems (19 percent), and more had no opinion (16 percent). There is little consistency in these results, and perhaps an underlying uncertainty is the best explanation for them. Non-Whites said *some* problems 35 percent of the time, *few* problems 19 percent, and *no* problems 23 percent, which is very high and, by itself, very favorable. However, the number with no opinion again is high, and perhaps some uncertainty is again being expressed by these numbers.

There have been numerous studies by previous investigators that bear on the above results. With regard to Table 6-6, La Porte and Metlay[o] studied the California population in 1972 and 1974 to determine how much of a change for the better or worse in life in general they believed that each of five technologies had made. The technologies were household

[o] T. La Porte and D. Metlay, "Public Attitudes Toward Present and Future Technologies: Satisfactions and Apprehensions", *Social Studies of Science*, Vol. 5 (1975), pp. 379-380.

appliances, automotive vehicles, automated factories, the space program, and atomic weapons. In 1974 computers, birth control pills, and television were added. Only atomic weapons received a largely negative reaction. Otherwise, the results were highly favorable, the least favorable being for the space program, where 61 percent in 1972 and 65 percent in 1974 reported that it makes life slightly or very much better.

The same authors have made further investigations of the public's attitude toward specific technologies.[10] In addition there have been many surveys, going back to 1957, dealing in a general way with the effects of science and/or technology.[11] They support the general conclusion that the public strongly favors science and technology for the improvements they have made in the standard of living. However, there is growing concern about their cultural side effects, e.g., on life-styles and values, and especially about the effects of new technologies.

While the public believes that science and technology have in some fashion caused problems, it is a further question *how* they think these problems arise. Scientists and engineers carry on their activities within an economic and social framework that involves many other agents as well. In particular, decisions are made within government and business that determine to a large extent how science and technology will be applied. When this application produces undesirable social and economic effects, it is of interest to know whether the public holds scientists and engineers responsible, or whether the decisionmakers are considered the responsible agents. In 1976 a first step was made in assessing the public's opinion about this, by asking those who had said that science and technology have caused at least a few problems which group is most at fault. Scientists and engineers were separately mentioned as possibilities, since it is important to know whether the public holds one group responsible more than the other. As Table 6-15 shows, most of the public considers government decisionmakers to be the group most responsible.

6-15. When science and technology cause problems, who is most at fault?

Response	Percent citing (1976)
Scientists	5
Technologists and engineers	7
Government decisionmakers	60
Business decisionmakers	14
Some other group	5
No opinion	9

SOURCE: Opinion Research Corporation, *op. cit.*, p. 20.

The emphasis on government decisionmakers is shared by all segments of the public. While this undoubtedly reflects a critical public attitude toward government, much of it may also be due to a feeling that government decisionmakers are the most powerful group when it comes to producing serious social changes. Business decisionmakers were a distant second at 14 percent, but they are cited by 21 percent of those with some college education and by 22 percent of those in professional occupations. These groups cited government decisionmakers slightly less frequently than did the public as a whole. Overall, technologists and engineers were mentioned slightly more often than scientists, but in both cases the percentages are quite low.

CAPABILITIES OF SCIENCE AND TECHNOLOGY

Another facet of its attitude toward science and technology is the public's feeling as to what they are able to accomplish. This is a matter of anticipating the future rather than interpreting the present or the past. While Table 6-14 in the

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[10] T. La Porte and D. Metlay, *They Watch and Wonder: Public Attitudes toward Advanced Technology* (December 1975). Final Report of the Institute of Governmental Studies, University of California, Berkeley, to Ames Research Center, National Aeronautics and Space Administration, NASA Grant NGR 05-003-0471, pp. 79, 149-152.

[11] T. La Porte and D. Metlay, "Technology Observed: Attitudes of a Wary Public", *Science*, Vol. 188 (April 11, 1975), p. 123.

The Harris Survey, Release of February 22, 1972.

G. R. Funkhouser, "Public Understanding of Science: The Data We Have", pp. 18-20, in G. R. Funkhouser, ed., *Final Report on Workshop on "Goals and Methods of Assessing the Public's Understanding of Science", November 29 and 30, 1972, Palo Alto, California*, NSF Grant No. GM 35058 (University Park: Pennsylvania State University, January 26, 1973).

Etzioni and Nunn, *op. cit.*, pp. 192-193.

National Opinion Research Center, Study 466 (May 1969), Question 31.

La Porte and Metlay, *They Watch and Wonder*, *op. cit.*, pp. 65, 69.

I. Taviss, "A Survey of Popular Attitudes Toward Technology", *Technology and Culture*, Vol. 13, No. 4 (October 1972), p. 609.

last section is concerned with the problems that science and technology are thought to have caused, Table 6-16 below shows the public's view of their ability to solve problems. There is a high degree of public confidence in the ability of science and technology to solve at least some of our problems.

6-16. Will science and technology eventually solve *most* problems such as pollution, disease, drug abuse, and crime, *some* of these problems, or *few if any* of these problems?

Response	Percent 1972	1974	1976
Most problems	30	23	27
Some problems	47	53	48
Few if any problems	16	20	19
No opinion	7	4	6

SOURCE: Opinion Research Corporation, *op. cit.*, p. 15.

In 1972, 30 percent had the most favorable feeling about science and technology, that they will solve most problems. This figure dropped sharply in 1974, but about half of this drop was recovered in 1976. In 1972 also, 16 percent thought they will solve few if any problems, while significantly more felt that way in 1974 and 1976. Thus there evidently was a declining belief in the capabilities of science and technology from 1972 to 1974, with some recovery by 1976.

Among related studies, public opinion was measured in 1958 on the issue of whether science will solve our social problems, like crime and mental illness.[12] This was agreed to by 44 percent. In 1974, the survey of the California population previously mentioned asked whether relying only on scientific and logical thinking to solve society's problems can only make things more complicated.[13] Forty-six percent agreed or agreed strongly, 4 percent were neutral, and 50 percent disagreed or disagreed strongly. Thus Table 6-16 and related studies show that on this issue the public is not as favorably disposed toward science and technology as it is on many of the other issues.

As was noted in the discussion of Table 6-14, scientific and technological activity takes place within a social and economic framework. Hence one may wonder whether the response on Table 6-16 means that the public expects science and technology to solve social problems without help from other fields, or whether they are only expected to make one contribution among many to the solution of these problems. One may also wonder whether the public expects science and technology to be able to contribute more in some problem areas than in others. A question to this effect was introduced in 1976. As Table 6-17 indicates, many members of the public believe that science and technology could at least make a major contribution in several problem areas, particularly health care and pollution.

The two areas in which the greatest confidence is expressed are also those in which the public believes that science and technology have done the most good and the most harm in the past, according to Tables 6-9 through 6-11. The typical member of the public is willing to name about 5 areas of the 13 presented to him in which science and technology could make a major contribution but only about 1 area where little or no contribution could be expected. Almost all members of the public are able to designate at least one area in which a major contribution is possible, while 39 percent are unable or unwilling to designate even one area in which science and technology can make little contribution. These facts suggest a high degree of confidence in science and technology.

For the most part, the areas where many feel a major contribution is possible are the same as the fields where few feel there can be little or no contribution. The major exception is in the area of reducing crime. Though this ranks third as an area for science and technology to make a major contribution, it is also first in order among areas where little or no contribution is expected. This indicates some kind of disagreement among different members of the public. Possibly many who say that major contributions are possible with regard to crime think of this as an area in which they would *like* to see some action taken, any action, to relieve the problems. Many who say little or no contribution is possible may mean more literally that crime is not an area in which science and technology can be effective.

The same point is suggested by the realtively low standing accorded to discovering new basic knowledge. Perhaps most of the public do not feel that science and technology are good for solving problems in this area, but it seems more

[12] Funkhouser, *op. cit.*, pp. 18-19.
[13] La Porte and Metlay, *They Watch and Wonder*, *op. cit.*, pp. 49, 58.

6-17. Areas in which science and technology could make a major contribution (little or no contribution) toward solving the problems

Area	Percent choosing[1] (1976) Major contribution	Little or no contribution
Improving health care	65	3
Reducing and controlling pollution	56	4
Reducing crime	51	19
Finding new methods for preventing and treating drug addition	48	7
Developing/improving methods of producing food	44	5
Improving education	42	12
Improving the safety of automobiles	39	6
Developing faster and safer public transportation	34	9
Discovering new basic knowledge about man and nature	30	11
Finding better birth control methods	30	12
Developing/improving weapons for national defense	28	12
Space exploration	26	13
Weather control and prediction	23	17
None of these	0	25
No opinion	5	14

[1] Multiple responses were accepted.

SOURCE: Opinion Research Corporation, *op. cit.*, pp. 52-55.

likely that they do not see an urgent need to attack such problems. Tables 6-9 and 6-10 show that the public values science and technology for the social benefits that they help achieve, not because it values basic knowledge for its own sake.[14]

PUBLIC PREFERENCES REGARDING SCIENCE AND TECHNOLOGY

Since science and technology are perceived to have certain capabilities and to cause certain problems, it is of interest to ask what the public would like to see done about them. In which areas do the expected benefits justify the spending of public money on science and technology? Should there be more control of science and technology? Table 6-17 above shows the areas in which the public feels science and technology could make a major contribution or little contribution. Table 6-18 shows that the areas in which the public would most and least like its tax money spent for science and technology are rather similar to the areas most and least favored on Table 6-17.

The typical member of the public cited about 3 areas in which he would most like his taxes spent and about 2 in which he would least like such money spent, out of the 13 areas offered. The preponderance of positive replies indicates a measure of public confidence in the ability of science and technology to help in solving problems. It is not as great, however, as the preponderance indicated on Table 6-17 of those who feel that science and technology would be effective in solving problems. The difference may be due to a reluctance to see tax money spent on public programs in general. By the same token, there was a greater number of areas in which the public would least like money spent, according to Table 6-18, than of areas where they would be ineffective, according to Table 6-17.

[14] A related study, on the usefulness of further technological development in solving various social problems, is reported in La Porte and Metlay, "Public Attitudes Toward Present and Future Technologies: Satisfactions and Apprehensions", *op. cit.*, pp. 373-398.

6-18. Areas in which taxes should be spent for science and technology

Area	Percent choosing[1] (1976) Would most like	Would least like
Improving health care	57	1
Reducing crime	37	3
Reducing and controlling pollution	33	2
Improving education	33	4
Finding new methods for preventing and treating drug addiction	24	4
Developing/improving methods of producing food	20	5
Improving the safety of automobiles	15	7
Developing faster and safer public transportation	13	14
Finding better birth control methods	10	19
Developing/improving weapons for national defense	10	24
Discovering new basic knowledge about man and nature	9	16
Space exploration	7	35
Weather control and prediction	5	18
None of these	1	6
No opinion	6	11

[1] Multiple responses were accepted.

SOURCE: Opinion Research Corporation, *op. cit.*, pp. 56-59.

The rank ordering of the areas listed on Table 6-18 is much the same as on Table 6-17. However, reducing crime seems to have a higher priority than reducing and controlling pollution. Doubts about the ability of science and technology to help in reducing crime are not translated into an unwillingness to see money spent on the effort. This is also true regarding improving education. This area moves up on the list, from sixth on Table 6-17 to fourth on Table 6-18. Misgivings about the ability of science and technology to help (as shown on Table 6-17) produce few negative votes for the attempt (on Table 6-18). On the other hand, discovering new basic knowledge about man and nature ranks higher as a capability of science and technology than as something the taxpayer would like to pay for. The fact that the rank orders are so much alike on the two tables confirms the impression that Table 6-17 really shows to a large extent the areas in which the public would *like* work to be done.

There is considerable consistency between the "most like" and "least like" columns on Table 6-18. The areas usually most liked are very seldom least liked, and inversely. The major exceptions are space exploration and national defense. Both receive an exceptional number of negative votes.[15]

Table 6-18 can be compared with the results of a study that the National Opinion Research Center made in 1976 as part of their General Social Survey. The main difference is that the General Social Survey simply asks whether we are spending too much or too little money in certain areas. Science and technology are not mentioned. The public's feelings about expenditures in these areas are indicated on Table 6-19.

Only 7 of the 11 items on the table correspond to items on Table 6-18. The latter does not list the problems of cities, the conditions of Blacks, welfare, or foreign aid. In spite of differences in the questions, there is some similarity between this table and the response on Table 6-18. Here the crime problem ranks ahead of health

[15] The same question was used in the 1972 and 1974 surveys, but since it was not preceded in those years by the question about the *capabilities* of science and technology, the results are not strictly comparable to the 1976 results shown on Table 6-18.

6-19. Are we spending too much money on this problem, too little money, or about the right amount?

Problem	Percent citing (1976) Too little	Too much
Halting the rising crime rate	65	8
Improving and protecting the Nation's health	60	5
Dealing with drug addition	58	8
Improving and protecting the environment	55	9
Improving the Nation's educational system	50	9
Solving the problems of the big cities	42	19
Improving the conditions of Blacks	27	25
The military, armaments, and defense	24	27
Welfare	13	60
Space exploration program	9	60
Foreign aid	3	75

SOURCE: National Opinion Research Center, University of Chicago, *Codebook for the Spring 1976 General Social Survey* (July 1976), Question 59.

(perhaps because the crime issue is expressed in inflammatory terms), and drug addiction is relatively more important in the NORC results than on Table 6-18. For the most part, however, the ordering is quite similar on the two tables. On both, space exploration and defense were among the least liked of the areas in which tax money might be spent. Thus it seems that the public has a certain set of priorities in the problems it wishes to see attacked, whether or not science and technology are part of that attack. It is conceivable, in fact, that the public, when asked about the problem areas in which tax money should be spent for science and technology, had very little idea how science and technology might bear on the problems listed, and that they were simply recording their concern about the problems themselves.

The public shows considerable confidence in the ability of science and technology to help in solving public problems. However, some public concern about science and technology is evidenced by the fact that about 30 percent wish to see society's control over them increased.

A plurality wish control to remain as it is, but there is also a sizable number wishing the

6-20. Should the degree of control that society has over science and technology be increased, be decreased, or remain as it is now?

Response	Percent 1972	1976
Increased	28	31
Decreased	7	10
Remain as it is	48	45
No opinion	17	14

SOURCE: Opinion Research Corporation, *op. cit.*, p. 50.

control to be increased. This number grew between 1972 and 1976, but so did the number wishing control to be decreased. In 1976, the desire to see control increased was especially great among professionals (41 percent) and low among farmers and farm laborers (18 percent), those 60 or over (24 percent), and those living in rural areas (25 percent). Those who especially wished control to be decreased included those living in the West (16 percent).

While there is some public interest in controlling science and technology, it is important to know whether there is a stronger feeling about controlling one or the other. A question to this effect was asked in 1976, with the result indicated on Table 6-21. Very little difference was discovered between the need to control science and the need to control technology, in the public's view.

6-21. Is it more important for society to control science, to control technology, to control both equally, or to control neither?

Response	Percent (1976)
Control science	2
Control technology	5
Control both equally	59
Control neither	20
No opinion	14

SOURCE: Opinion Research Corporation, *op. cit.*, p. 51.

This table should be compared with Table 6-15, which also differentiates public attitudes toward science and toward technology. In both cases the percentages of those critical of science and technology are quite low, but there is somewhat more concern about technology. Also in the case of both questions, there is a

significant demographic group that is somewhat more worried about technology. Thus 11 percent of those with some college education and 11 percent of professionals thought in 1976 that it is more important to control technology. No group had that strong a percentage in favor of controlling science. Of the lowest income group, below $5,000 per year, 27 percent had no opinion; 26 percent of the rural respondents and those 60 or over and 23 percent of those who had not completed high school also had no opinion. This suggests that these groups are uncertain about the difference between science and technology.

There were 20 percent of the total public who thought neither science nor technology was more in need of control, which suggests that these people wanted to see less control of science and technology than there is now. But this greatly exceeds the 10 percent recorded on Table 6-21 who felt in 1976 that control should be decreased. Presumably public attitudes are more consistent with regard to more specific issues, such as the problem areas listed on Table 6-18.

The question whether the public distinguishes science from technology was also discussed by Etzioni and Nunn,[16] who did not find that it makes such a distinction, and by La Porte and Metlay,[17] who did. The latter authors used a number of questions in 1972 and 1974 that probe the public's desire to control science or technology.

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[16] Etzioni and Nunn, *op. cit.*, pp. 195f.

[17] La Porte and Metlay, *They Watch and Wonder*, *op. cit.*, Chapter III.

Appendix Tables

Table 1-1. National expenditures for performance of R&D as a percent of Gross National Product (GNP) by country, 1961-76

Year	Canada	France	West Germany	Japan	United Kingdom	United States	U.S.S.R.
	R&D expenditures as a percent of Gross National Product[1]						
1961	1.01	1.38	NA	NA	2.69	2.74	NA
1962	.95	1.43	1.25	1.48	NA	2.73	2.18
1963	.95	1.53	1.40	NA	NA	2.87	2.37
1964	1.05	1.78	1.56	NA	2.62	2.97	2.42
1965	1.17	1.99	1.72	1.55	NA	2.92	2.40
1966	1.21	2.07	1.80	1.50	2.68	2.91	2.42
1967	1.33	2.16	1.97	1.55	2.69	2.91	2.55
1968	1.33	2.12	1.95	1.51	2.65	2.84	NA
1969	1.34	1.96	2.02	1.71	2.63	2.75	2.62
1970	1.29	1.88	2.16	1.86	NA	2.65	2.79
1971	1.25	1.87	2.36	1.88	NA	2.50	2.85
1972	1.17	1.83	2.31	1.89	2.39	2.43	3.13
1973	1.11	1.73	2.22	1.92	NA	2.33	3.19
1974	1.09	NA	2.23	1.99	NA	2.29	3.13
1975	NA	1.48	2.25	NA	NA	2.32	3.18
1976	NA	NA	2.13	NA	NA	2.25	NA
	R&D expenditures (national currency in billions)[2]						
1961	.39	4.4	NA	NA	.66	14.3	3.8
1962	.40	5.2	4.5	321.1	NA	15.4	4.3
1963	.44	6.3	5.4	NA	NA	17.1	4.9
1964	.53	8.1	6.6	NA	.77	18.9	5.4
1965	.65	9.8	7.9	508.6	NA	20.1	5.8
1966	.75	11.0	8.8	576.6	.89	21.9	6.3
1967	.88	12.4	9.7	702.5	.94	23.2	7.2
1968	.96	13.3	10.6	877.5	1.00	24.7	7.9
1969	1.07	14.2	12.3	1,064.7	1.05	25.7	8.6
1970	1.10	15.2	14.8	1,355.5	NA	26.0	10.1
1971	1.17	16.8	18.0	1,532.4	NA	26.7	11.3
1972	1.22	18.3	19.3	1,791.9	1.31	28.4	12.6
1973	1.33	19.8	20.6	2,215.8	NA	30.4	13.7
1974	1.52	NA	22.2	2,716.0	NA	32.3	14.2
1975	NA	22.5	23.5	NA	NA	35.2	15.0
1976	NA	NA	24.2	NA	NA	38.1	NA

(Continued)

Table 1-1. (Continued)

Year	Canada	France	West Germany	Japan	United Kingdom	United States	U.S.S.R.
	Gross National Product (national currency in billions)						
1961	39.1	320.0	333.0	19,852.8	24.5	523.3	NA
1962	42.4	367.2	360.1	21,649.5	25.6	563.8	197.2
1963	46.0	412.0	384.0	25,592.1	27.3	594.7	206.8
1964	50.3	456.7	420.9	29,661.9	29.5	635.7	223.2
1965	55.4	489.8	460.4	32,813.7	31.5	688.1	242.1
1966	61.8	532.0	490.7	34,418.6	33.2	753.0	260.1
1967	66.4	574.0	495.5	45,296.7	35.0	796.3	282.0
1968	72.6	629.0	540.0	58,288.2	37.7	868.5	NA
1969	79.8	723.0	605.2	62,259.9	39.7	935.5	329.6
1970	85.7	808.0	685.6	73,046.1	43.5	982.4	362.6
1971	93.5	899.0	761.9	81,577.0	48.9	1,063.4	394.8
1972	104.0	1,002.0	833.9	94,726.5	54.9	1,171.1	401.8
1973	120.4	1,143.0	926.9	115,600.0	63.3	1,306.6	429.4
1974	139.3	1,314.0	997.0	136,300.0	NA	1,413.2	453.1
1975	154.8	1,522.0	1,043.0	153,707.0	NA	1,516.3	472.2
1976	NA	NA	1,135.1	NA	NA	1,691.6	NA

[1] Calculated from unrounded figures.

[2] Gross expenditures for performance of R&D including associated capital expenditures, except for the United States and the U.S.S.R. where total capital expenditure data are not available.

NA = not available.

NOTE: Estimates are shown for 1974, 1975, and 1976. United Kingdom R&D figures for 1968-69 are shown as 1968, 1969-70 as 1969, and 1972-73 as 1972.

SOURCES: United States: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), p. 28; Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, January 1976; and *Commerce News*, March 21, 1977. U.S.S.R.: Robert W. Campbell, Department of Economics, Indiana University. Other countries: National Science Foundation, Division of Science Resources Studies, Industry Studies Group, unpublished data.

See Figure 1-1 in text.

Table 1-2. Scientists and engineers[1] engaged in R&D by country, 1965-75

Country	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
	Scientists and engineers[1] engaged in R&D per 10,000 population										
Canada	7.7	NA	9.5	NA	10.0	9.6	10.4	10.4	10.5	NA	NA
France	8.8	9.3	10.2	10.6	10.9	11.6	11.8	11.9	11.6	NA	NA
West Germany	9.7	10.1	10.5	11.3	12.5	13.5	14.7	15.4	16.3	16.4	16.7
Japan	11.9	12.9	13.8	15.5	15.2	16.5	18.4	18.5	21.1	21.9	NA
United Kingdom	10.1	NA	NA	7.9	NA	NA	NA	13.8	NA	NA	NA
United States	25.4	26.5	26.9	27.4	27.5	26.8	25.6	25.0	24.8	24.9	24.8
U.S.S.R.	21.6	23.9	25.7	27.3	29.1	30.7	32.6	34.3	37.3	43.2	43.8
	Scientists and engineers engaged in R&D (in thousands)										
Canada	15.1	NA	19.3	NA	21.0	20.4	22.4	22.8	23.2	NA	NA
France	42.8	45.7	50.7	53.1	54.7	59.0	60.5	61.6	60.2	NA	NA
West Germany	57.0	60.0	63.1	68.0	76.3	82.0	90.2	95.0	101.0	102.0	103.0
Japan	118.0	129.0	139.0	158.0	157.0	172.0	194.0	198.0	227.0	238.0	NA
United Kingdom	54.6	NA	NA	43.6	NA	NA	NA	77.1	NA	NA	NA
United States	494.1	521.1	534.4	550.4	558.2	549.6	529.8	521.9	521.1	527.2	530.5
U.S.S.R.	499.4	558.4	605.6	651.5	698.9	746.2	797.8	848.8	931.0	1,090.0	1,115.0
	Population (in thousands)										
Canada	19,680	20,050	20,410	20,730	21,030	21,320	21,568	21,850	22,130	22,090	22,801
France	48,760	49,160	49,550	49,910	50,320	50,770	51,250	51,700	51,900	52,410	52,913
West Germany	59,010	59,640	59,870	60,180	60,850	60,650	61,290	61,670	61,980	62,050	61,682
Japan	98,880	99,790	100,830	101,960	103,170	104,340	105,600	106,960	107,370	108,630	111,120
United Kingdom	54,180	54,450	54,750	55,050	55,270	55,410	55,506	55,800	55,930	56,890	56,427
United States	194,303	196,560	198,712	200,706	202,677	204,875	207,045	208,842	210,396	211,910	213,925
U.S.S.R.	230,936	233,533	235,994	238,317	240,554	242,757	245,083	247,459	249,747	252,065	254,393

[1] Includes all scientists and engineers on a full-time-equivalent basis (except for Japan whose data include persons primarily employed in R&D and the United Kingdom whose data include only the government and industry sectors).

NOTE: Estimates are shown for all countries for 1974 and 1975 and for the United States for 1966 and 1967.

SOURCE: United Nations, *Demographic Yearbook, 1973*, p. 101, and United Nations Population Division, Department of Economic and Social Affairs, *Selected World Demographic Indicators by Countries, 1950-2000*, 1975. United States: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), p. 32. U.S.S.R.: Robert W. Campbell, Department of Economics, Indiana University, and Council for Mutual Economic Assistance, *Statistical Yearbook of the Member Countries*, 1971 and 1972, pp. 7 and 12. Other countries: National Science Foundation, Division of Science Resources Studies, Industries Studies Group, unpublished data.

See Figure 1-2 in text.

Table 1-3. Estimated distribution of Government R&D expenditures among selected areas by country, 1961-73

National objectives	National currency in millions				Percent distribution			
Canada	1961-62	1966-67	1970-71	1974-75	1961-62	1966-67	1970-71	1974-75
National defense	39.8	57.9	51.0	63.9	24	17	9	8
Space	NA	6.0	7.4	32.4	NA	2	1	4
Energy production	30.4	69.3	98.6	117.9	18	21	18	14
Economic development	76.0	143.3	275.5	356.9	46	43	50	43
Health	6.3	24.4	54.9	71.6	4	7	10	9
Community services	.5	6.2	13.1	97.7	([1])	2	2	12
Advancement of knowledge[2]	13.5	26.8	44.8	85.0	8	8	8	10

(Continued)

Table 1-3. (Continued)

National objectives	National currency in millions				Percent distribution			
France	1961	1967	1972	1975	1961	1967	1972	1975
National defense	1,310.0	3,082.0	3,050.0	5,000.0	44	35	28	30
Space	16.5	522.8	730.0	942.2	1	6	7	6
Energy production	735.0	1,723.2	1,600.0	1,453.0	25	20	15	9
Economic development	231.6	1,381.0	2,200.0	4,329.4	8	16	20	26
Health	13.0	116.1	200.0	680.2	(1)	1	2	4
Community services	12.7	81.0	170.0	328.7	(1)	1	2	2
Advancement of knowledge	592.3	1,758.1	2,800.0	4,072.2	20	20	26	24
Japan	1961-62	1965-66	1969-70	1974-75	1961-62	1965-66	1969-70	1974-75
National defense	3,162.0	4,495.0	6,523.0	15,809.0	4	3	2	2
Space	—	141.0	2,083.0	37,090.0	—	(1)	1	5
Energy production	5,881.0	4,944.0	22,539.0	59,409.0	7	3	8	8
Economic development	25,446.0	44,898.0	69,987.0	161,796.0	30	27	23	23
Health	724.0	3,679.0	5,492.0	21,424.0	1	2	2	3
Community services	1,071.0	2,818.0	7,254.0	18,129.0	1	2	2	3
Advancement of knowledge	47,321.0	103,163.0	185,376.0	388,700.0	56	63	61	55
United Kingdom	1961-62	1966-67	1972-73	1974-75	1961-62	1966-67	1972-73	1974-75
National defense	248.6	260.4	336.8	503.1	65	52	43	47
Space	2.7	21.4	15.3	22.5	1	4	2	2
Energy production	56.5	65.2	69.6	68.6	15	13	9	6
Economic development	37.9	70.9	182.8	230.6	10	14	23	21
Health	5.7	13.3	39.1	22.6	2	3	5	2
Community services	.7	2.2	8.3	13.1	(1)	(1)	1	1
Advancement of knowledge	26.0	58.4	121.8	214.9	7	12	15	20
United States[3]	1961-62	1966-67	1971-72	1974-75	1961-62	1966-67	1971-72	1974-75
National defense	7,338.5	8,264.8	8,584.7	9,620.9	71	49	53	51
Space	1,225.9	5,307.0	2,957.6	2,511.3	12	32	18	13
Energy production	755.0	875.0	838.0	1,163.9	7	5	5	6
Economic development	339.1	792.3	1,322.1	1,784.2	3	5	8	9
Health	500.6	968.8	1,379.8	2,247.4	5	6	9	12
Community services	99.9	321.1	729.2	954.6	1	2	5	5
Advancement of knowledge[2]	118.2	308.6	465.4	761.9	1	2	3	4
West Germany	1961	1966	1971	1975	1961	1966	1971	1975
National defense	381.0	803.0	1,180.0	1,405.0	22	19	15	11
Space	—	177.0	522.0	539.9	—	4	6	4
Energy production	267.0	693.0	1,230.0	1,342.9	16	16	16	11
Economic development	NA	NA	1,057.0	1,729.5	NA	NA	13	14
Health	NA	NA	195.0	414.6	NA	NA	3	3
Community services	NA	NA	133.0	748.7	NA	NA	2	6
Advancement of knowledge	639.0	1,488.0	3,190.0	6,430.7	37	35	41	51

[1] Less than 0.5 percent.
[2] Excludes general university funds.
[3] Function categories are not the same as those of Appendix Table 2-11; e.g., "Advancement of Knowledge" does not equal "Science and Technology base."

NOTE: Percents may not total 100 because of exclusion of the category "Not specified" and/or due to rounding.

SOURCE: Organisation for Economic Co-operation and Development, *Changing Priorities for Government R&D* (Paris: OECD, 1975), and OECD, *International Statistical Year-1973: The Objectives of Government R&D Funding, 1970-76* Vol. 2B (Paris: OECD, 1977).

See Figure 1-3 in text.

Table 1-4. Distribution of publications[1] in U.S. journals by field and country of author, 1975

Field[2]	Number	Percent distribution by country of authors								
		United States	United Kingdom	West Germany	France	U.S.S.R.	Japan	Canada	All other countries	Total
All fields	117,362	73	4	2	2	1	3	5	12	100
Clinical medicine	34,316	79	3	1	1	(3)	2	4	11	100
Biomedical research .	16,884	71	4	2	3	(3)	3	4	12	100
Biology	10,697	82	2	1	1	(3)	1	5	9	100
Chemistry	13,215	55	5	3	5	3	7	4	17	100
Physics	13,568	66	4	4	4	1	3	4	14	100
Earth and space sciences	5,528	76	3	1	1	1	1	6	11	100
Engineering and technology	13,839	71	5	2	1	1	3	5	11	100
Psychology	5,588	84	3	(3)	(3)	(3)	(3)	6	6	100
Mathematics	3,726	73	4	2	1	(3)	1	7	12	100

[1] Includes 117,000 articles, notes and reviews from the influential U.S. journals in the *Science Citation Index* Corporate Tape, 1975. Corporate tape data used throughout this section include only those publications carrying the author's place of employment or affiliation.
[2] See Appendix Table 1-5 for the subfields included in these fields.
[3] Less than 0.5 percent.

NOTE: Detail may not add to totals because of rounding.

SOURCE: Computer Horizons, Inc., unpublished data.

See Figure 1-5 in text.

Table 1-5. Fields and subfields of international scientific literature

- Clinical medicine
  - General and internal medicine
  - Allergy
  - Anesthesiology
  - Cancer
  - Cardiovascular system
  - Dentistry
  - Dermatology & venereal diseases
  - Endocrinology
  - Fertility
  - Gastroenterology
  - Geriatrics
  - Hematology
  - Immunology
  - Obstetrics & gynecology
  - Neurology & neurosurgery
  - Ophthalmology
  - Orthopedics
  - Arthritis & rheumatism
  - Otorhinolaryngology
  - Pathology
  - Pediatrics
  - Pharmacology
  - Pharmacy
  - Psychiatry
  - Radiology & nuclear medicine
  - Respiratory system
  - Surgery
  - Tropical medicine
  - Urology
  - Nephrology
  - Veterinary medicine
  - Addictive diseases
  - Hygiene & public health
  - Miscellaneous clinical medicine
- Biology and biomedical research
  - Biomedical research
    - Physiology
    - Anatomy & morphology
    - Embryology
    - Genetics & heredity
    - Nutrition & dietetics
    - Biochemistry & molecular biology
    - Biophysics
    - Cell biology cytology & histology
    - Microbiology
    - Virology
    - Parasitology
    - Biomedical engineering
    - Microscopy
    - Miscellaneous biomedical research
    - General biomedical research
  - Biology
    - General biology
    - General zoology
    - Entomology
    - Miscellaneous zoology
    - Marine biology & hydrobiology
    - Botany
    - Ecology
    - Agriculture & food science
    - Dairy & animal science
    - Miscellaneous biology
- Chemistry
  - Analytical chemistry
  - Organic chemistry
  - Inorganic & nuclear chemistry
  - Applied chemistry
  - General chemistry
  - Polymers
  - Physical chemistry
- Physics
  - Chemical physics
  - Solid state physics
  - Fluids & plasmas
  - Applied physics
  - Acoustics
  - Optics
  - General physics
  - Nuclear & particle physics
  - Miscellaneous physics
- Earth and space science
  - Astronomy & astrophysics
  - Meteorology and atmospheric science
  - Geology
  - Earth & planetary science
  - Geography
  - Oceanography & limnology
- Engineering and technology
  - Chemical engineering
  - Mechanical engineering
  - Civil engineering
  - Electrical engineering & electronics
  - Miscellaneous engineering & technology
  - Industrial engineering
  - General engineering
  - Metals & metallurgy
  - Materials science
  - Nuclear technology
  - Aerospace technology
  - Computers
  - Library & information science
  - Operations research & management science
- Psychology
  - Clinical psychology
  - Personality & social psychology
  - Developmental & child psychology
  - Experimental psychology
  - General psychology
  - Miscellaneous psychology
  - Behavioral science
- Mathematics
  - Algebra
  - Analysis & functional analysis
  - Geometry
  - Logic
  - Number theory
  - Probability
  - Statistics
  - Topology
  - Computing theory & practice
  - Applied mathematics
  - Combinatorics & finite mathematics
  - Physical mathematics
  - General mathematics
  - Miscellaneous mathematics

Table 1-6. Citations from the publications[1] of all countries to previous U.S. publications, by country and field, 1975

Field[2]	All countries	Country of citation to U.S. publication: United States	United Kingdom	West Germany	France	U.S.S.R.	Japan	Canada	All other countries
					Number				
All fields	1,847,512	885,613	173,286	99,783	86,103	49,833	82,778	85,714	384,399
Clinical medicine	598,352	305,273	54,303	32,803	29,784	5,457	17,335	23,835	129,562
Biomedical research	456,657	217,549	44,566	23,847	20,583	10,119	23,203	20,310	96,431
Biology	115,191	59,726	11,535	4,286	3,650	1,130	3,227	8,821	22,816
Chemistry	206,228	71,312	23,369	13,503	11,348	10,431	16,816	9,569	49,879
Physics	230,465	94,450	19,236	16,075	13,052	15,467	14,426	9,427	48,333
Earth & space sciences	92,533	52,650	8,340	3,398	3,546	3,025	2,004	4,801	14,768
Engineering & technology	69,802	33,631	6,261	3,582	2,250	3,271	4,416	3,798	12,591
Psychology	51,484	37,032	3,386	787	768	302	554	3,496	5,158
Mathematics	26,800	13,990	2,290	1,452	1,122	631	797	1,657	4,861
					Percent distribution across countries				
All fields	100	48	9	5	5	3	4	5	21
Clinical medicine	100	51	9	5	5	1	3	4	22
Biomedical research	100	48	10	5	5	2	5	4	21
Biology	100	52	10	4	3	1	3	8	20
Chemistry	100	35	11	7	6	5	8	5	24
Physics	100	41	8	7	6	7	6	4	21
Earth & space sciences	100	57	9	4	4	3	2	5	16
Engineering & technology	100	48	9	5	3	5	6	5	18
Psychology	100	72	7	2	1	1	1	7	10
Mathematics	100	52	9	5	4	2	3	6	18

[1] From a study of over 276,000 articles, notes and reviews from the 2,400 influential journals of the *Science Citation Index* Corporate Tape, 1975.
[2] See Appendix Table 1-5 for the subfields included in these fields.

NOTE: Detail may not add to totals because of rounding.

SOURCE: Computer Horizons, Inc., unpublished data.

See Text Table 1-6.

Table 1-7. Distribution of the publications[1] of U.S. authors by country of journal and field, 1975

Field[2]	Number	Percent distribution by country of journal								
		United States	United Kingdom	West Germany	France	U.S.S.R.	Japan	Canada	All other countries	Total
All fields	105,940	80	8	2	(3)	(3)	(3)	1	9	100
Clinical medicine	32,276	84	6	2	(3)	—	(3)	(3)	8	100
Biomedical research	16,310	73	12	3	(3)	—	(3)	1	10	100
Biology	10,866	81	10	2	(3)	—	(3)	3	4	100
Chemistry	9,459	76	8	2	(3)	(3)	(3)	(3)	13	100
Physics	11,642	76	5	1	(3)	(3)	1	(3)	17	100
Earth & space sciences	5,219	80	8	3	(3)	(3)	(3)	1	8	100
Engineering & technology	11,166	88	6	(3)	(3)	—	(3)	1	4	100
Psychology	5,275	89	10	(3)	(3)	—	(3)	(3)	1	100
Mathematics	3,729	73	6	7	1	(3)	1	3	8	100

[1] Includes 106,000 articles, notes and reviews written by U.S. authors in the 2,400 influential journals of the *Science Citation Index* Corporate Tape, 1975.
[2] See Appendix Table 1-5 for the subfields included in these fields.
[3] Less than 0.5 percent.

NOTE: Detail may not add to totals because of rounding.

SOURCE: Computer Horizons, Inc., unpublished data.

See Figure 1-8 in text.

Table 1-8. Citations from U.S. publications[1] to previous publications, by cited country and field, 1975

Field[2]	All countries	Cited country: United States	United Kingdom	West Germany	France	U.S.S.R.	Japan	Canada	All other countries
	Number								
All fields	1,531,322	885,613	152,498	59,332	48,112	21,071	50,397	71,736	242,568
Clinical medicine	485,380	305,273	52,641	10,830	9,267	843	11,555	17,578	77,393
Biomedical research	384,653	217,549	40,919	17,307	14,280	3,207	13,873	16,840	60,678
Biology	99,440	59,726	9,703	2,880	1,942	394	2,665	7,164	14,967
Chemistry	166,599	71,312	17,349	12,109	8,510	4,237	10,282	8,846	33,955
Physics	184,006	94,450	13,254	10,495	9,411	9,031	8,005	8,340	31,020
Earth & space sciences	83,722	52,650	7,638	2,186	2,321	1,683	1,418	4,573	11,254
Engineering & technology	55,795	33,631	5,949	2,079	997	1,065	1,831	2,970	7,274
Psychology	47,352	37,032	2,768	292	318	23	171	4,021	2,727
Mathematics	24,375	13,990	2,277	1,154	1,066	588	597	1,404	3,300
	Percent distribution across countries								
All fields	100	58	10	4	3	1	3	5	16
Clinical medicine	100	63	11	2	2	([3])	2	4	16
Biomedical research	100	57	11	4	4	1	4	4	16
Biology	100	60	10	3	2	([3])	3	7	15
Chemistry	100	43	10	7	5	3	6	5	20
Physics	100	51	7	6	5	5	4	5	17
Earth & space sciences	100	63	9	3	3	2	2	5	13
Engineering & technology	100	60	11	4	2	2	3	5	13
Psychology	100	78	6	1	1	([3])	([3])	8	6
Mathematics	100	57	9	5	4	2	2	6	14

[1] Based on 106,000 articles, notes and reviews written by U.S. authors in the 2,400 influential journals of the *Science Citation Index* Corporate Tape, 1975.
[2] See Appendix Table 1-5 for the subfields included in these fields.
[3] Less than 0.5 percent.

NOTE: Detail may not add to totals because of rounding.

SOURCE: Computer Horizons, Inc., unpublished data.

See Text Table 1-9.

Table 1-9. Publications[1] by U.S. authors which were co-authored at different institutions or organizations, by field and country, 1973

Type of co-authorship[2] and country	All fields[3]	Clinical medicine	Bio-medical research	Biology	Chemistry	Physics	Earth and space sciences	Engi-neering and technology	Psy-chology	Mathe-matics
All U.S. co-authorship	35,592	15,413	5,559	2,862	2,030	3,411	1,804	2,347	1,217	949
International co-authorship .	4,920	1,166	814	442	492	805	424	342	113	320
United Kingdom	786	172	139	50	78	155	74	51	15	50
West Germany	433	91	79	27	41	97	40	28	6	22
France	327	64	57	10	45	88	27	14	2	19
U.S.S.R.	33	3	5	3	1	7	9	2	—	2
Japan	313	75	61	27	43	43	22	25	—	17
Canada	793	167	103	79	80	89	83	70	57	65
All other countries	2,235	594	370	246	204	326	169	152	33	145

[1] Articles, notes and reviews from the 2,400 influential journals of the *Science Citation Index* Corporate Tape, 1973.
[2] Cooperative authorship as defined here includes publications whose authors were affiliated with different organizations. International cooperative authorship is indicated when the authors' affiliations are from different countries.
[3] See Appendix Table 1-5 for subfields included in these fields.

NOTE: Detail may not add to totals because of rounding.

SOURCE: Computer Horizons, Inc., unpublished data.

See Figure 1-10 in text.

Table 1-10. International cooperative authorship[1] of U.S. publications[2] as a percent of all cooperative authorship by U.S. authors, by country and field, 1973

Field[3]	Number of all cooperatively authored U.S. publications[4]	Number of international cooperatively authored U.S. publications	Percent international
All fields	35,592	4,920	13.8
Clinical medicine	15,413	1,166	7.6
Biomedical research ..	5,559	814	14.7
Biology	2,862	442	15.4
Chemistry	2,030	492	24.2
Physics	3,411	805	23.6
Earth & space sciences	1,804	424	23.5
Engineering & technology	2,347	342	14.6
Psychology	1,217	113	9.3
Mathematics	949	320	33.7

[1] International cooperative authorship is defined as the coauthoring of a publication by scientists and engineers whose places of employment or affiliation are in different countries.
[2] Articles, notes and reviews from the 2,400 influential journals of the *Science Citation Index* Corporate Tape, 1973.
[3] See Appendix Table 1-5 for subfields included in these fields.
[4] Cooperative authorship as defined here includes publications whose authors were affiliated with different organizations.

NOTE: Detail may not add to totals because of rounding.

SOURCE: Computer Horizons, Inc., unpublished data.

See Figure 1-10 in text.

Table 1-11. Participation in international scientific congresses, 1961-76

Year	Number of congresses	Total participants	U.S. participants	Non-U.S. participants
1961-62	17	25,811	6,738	19,073
1963-64	20	26,585	7,291	19,294
1965-66	24	41,417	6,876	34,541
1967-68	26	29,710	8,142	21,568
1969-70	28	37,494	9,986	27,508
1971-72	31	43,503	8,409	35,094
1973-74	52	48,533	13,191	35,342
1975-76	41	48,995	10,978	38,017
Total	239	302,048	71,611	230,437

SOURCE: National Academy of Sciences, unpublished data.

See Figure 1-11 in text.

Table 1-12. Number of Nobel Prize laureates in science by field and by country, 1901-76[1]

Period	Total	United States	France	West Germany[2]	U.S.S.R.	United Kingdom	Other countries
	Number of laureates in physics						
1901-1915	20	1	4	5	—	4	6
1916-1930	16	2	2	5	—	3	4
1931-1945	13	4	—	2	—	3	4
1946-1960	25	13	—	—	3	6	3
1961-1976[3]	32	17	2	2	3	4	4
Total	106	37	8	14	6	20	21
	Number of laureates in chemistry						
1901-1915	16	1	4	6	—	2	3
1916-1930	12	—	—	6	—	3	3
1931-1945	16	3	2	6	—	2	3
1946-1960	20	8	—	3	1	6	2
1961-1976	25	9	—	3	—	8	5
Total	89	21	6	24	1	21	16
	Number of laureates in physiology/medicine						
1901-1915	16	1	2	4	2	1	6
1916-1930	13	1	1	1	—	2	8
1931-1945	20	7	—	3	—	6	4
1946-1960	29	17	—	1	—	2	9
1961-1976	40	21	3	3	—	8	5
Total	118	47	6	12	2	19	32

[1] Presented by location of award-winning research and by date of award.
[2] Includes East Germany before 1946.
[3] This period consists of 16 years rather than 15.

SOURCE: The Nobel Foundation, *Les Prix Nobel*, annual series, and others.

See Figure 1-12 in text.

Table 1-13. Total Nobel Prize laureates in chemistry, physics, and physiology/medicine for selected countries, 1901-76[1]

Period	Total	United States	France	West Germany[2]	U.S.S.R.	United Kingdom	Other countries
1901-1915	52	3	10	15	2	7	15
1916-1930	41	3	3	12	—	8	15
1931-1945	49	14	2	11	—	11	11
1946-1960	74	38	—	4	4	14	14
1961-1976[3]	97	47	5	8	3	20	14
Total	313	105	20	50	9	60	69

[1] Presented by location of award-winning research and by date of award.
[2] Includes East Germany before 1946.
[3] This period consists of 16 years rather than 15.

SOURCE: The Nobel Foundation, *Les Prix Nobel*, annual series, and others.

See Figure 1-13 in text.

Table 1-14. Nobel Prize laureates in science proportionate to population for selected countries, 1901-76

Period[1]	United States	United Kingdom	West Germany[2]	France	U.S.S.R.	Switzer-land	Nether-lands
	Average number of Nobel Prizes per 10 million population per year						
1901-1910	.011	.115	.198	.153	.014	.278	.727
1911-1920	.018	.067	.113	.101	—	.513	.156
1921-1930	.023	.156	.221	.075	—	—	.270
1931-1940	.062	.149	.230	.049	—	.488	.119
1941-1950	.092	.142	.091	—	—	.667	—
1951-1960	.172	.174	.057	—	.020	—	.093
1961-1970	.128	.222	.086	.104	.013	—	—
1971-1976[2]	.175	.238	.082	—	—	.278	—
	Number of Nobel Prizes awarded						
1901-1910	1	5	12	6	2	1	4
1911-1920	2	3	7	4	—	2	1
1921-1930	3	7	8	3	—	—	2
1931-1940	9	7	9	2	—	2	1
1941-1950	14	7	4	—	—	3	—
1951-1960	29	9	3	—	4	—	1
1961-1970	25	12	5	5	3	—	—
1971-1976	22	8	3	—	—	1	—
Total	105	58	51	20	9	9	9
	Average population (in millions)						
1901-1910	93.4	43.4	60.7	39.3	138.5	3.6	5.5
1911-1920	110.2	44.7	62.1	39.4	152.5	3.9	6.4
1921-1930	128.3	44.8	36.3[3]	40.0	167.0	4.0	7.4
1931-1940	144.5	47.0	39.1	41.2	187.0	4.1	8.4
1941-1950	152.4	49.4	44.2	41.5	187.5	4.5	9.5
1951-1960	168.8	51.6	52.7	43.7	197.2	5.0	10.8
1961-1970	195.6	54.0	58.1	48.2	228.5	5.6	12.1
1971-1976[4]	209.4	56.0	61.2	51.8	248.9	6.0	13.1

[1] Presented by location of award-winning research and by date of award.
[2] Includes East Germany before 1946.
[3] The drop in German population was due to military casualties and territorial losses under the Versailles Treaty.
[4] This period consists of only 6 years rather than 10.

SOURCE: The Nobel Foundation, *Les Prix Nobel*, annual series; Department of Commerce, *Historical Statistics of the United States, Colonial Times to 1970*, 1976; United Nations, *World.Population Prospects*, 1966, and *Economic Survey of Europe in 1974*, Part II, 1975; and United Nations Population Division, Department of Economic and Social Affairs, *Selected World Demographic Indicators by Countries, 1950-2000*, 1975.

See Figure 1-14 in text.

Table 1-15. U.S. patent balance with selected countries, 1966-75

Country	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Total:										
Balance	36,066	34,469	36,045	35,885	33,697	31,445	30,520	25,129	19,795	19,197
Granted to U.S.	45,633	44,385	45,168	47,825	45,918	47,311	47,359	41,391	38,096	37,482
Granted by U.S.	9,567	9,916	9,123	11,940	12,221	15,866	16,839	16,262	18,301	18,285
Canada:										
Balance	15,676	16,592	16,686	18,153	17,598	16,665	16,045	11,619	11,460	10,891
Granted to U.S.	16,614	17,583	17,583	19,147	18,663	17,992	17,289	12,964	12,785	12,220
Granted by U.S.	938	991	897	994	1,065	1,327	1,244	1,345	1,325	1,329
West Germany:										
Balance	-248	-360	362	-40	-1,552	-1,128	-1,153	-639	-2,243	-2,929
Granted to U.S.	3,733	3,406	3,804	4,483	2,882	4,393	4,575	4,949	3,913	3,140
Granted by U.S.	3,981	3,766	3,442	4,523	4,434	5,521	5,728	5,588	6,156	6,069
Japan:										
Balance	3,561	2,008	3,439	2,505	2,149	1,667	794	546	-1,457	-1,421
Granted to U.S.	4,683	3,432	4,903	4,657	4,774	5,700	5,948	5,485	4,432	4,918
Granted by U.S.	1,122	1,424	1,464	2,152	2,625	4,033	5,154	4,939	5,889	6,339
United Kingdom:										
Balance	11,440	10,877	10,107	9,503	9,776	9,226	9,837	8,866	7,831	8,436
Granted to U.S.	14,117	13,676	12,588	12,678	12,728	12,682	13,001	11,717	10,976	11,497
Granted by U.S.	2,677	2,799	2,481	3,175	2,952	3,456	3,164	2,851	3,145	3,061
Other E.E.C. countries[1]:										
Balance	5,700	5,432	5,481	5,840	5,743	5,143	5,093	4,914	4,489	4,372
Granted to U.S.	6,483	6,253	6,225	6,777	6,670	6,346	6,287	6,071	5,783	5,455
Granted by U.S.	783	821	744	937	927	1,203	1,194	1,157	1,294	1,083
U.S.S.R.:										
Balance	-63	-80	-30	-76	-17	-128	-96	-177	-285	-152
Granted to U.S.[2]	3	35	65	83	201	198	259	205	207	252
Granted by U.S.	66	115	95	159	218	326	355	382	492	404

[1] Other European Economic Community (E.E.C.) countries included here are Belgium, Denmark, Ireland, Luxembourg, and the Netherlands. Data for France and Italy are not comparable for use in this indicator.
[2] Includes inventors certificates.

SOURCE: World Intellectual Property Organization, *Industrial Property,* Geneva: 1967-76 (December issues).

See Figure 1-15 in text.

Table 1-16. Number of U.S. patents granted to selected foreign countries[1] by product field, 1963-75

Country	Total	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Total	986,839	9,532	9,181	129,243	16,767	11,572	42,825	19,244	10,980	110,955	273,237	95,734	101,182	50,333	15,077	90,777
United States ...	721,347	6,981	6,337	86,835	9,850	10,162	32,819	14,684	7,399	86,774	197,905	72,315	76,430	36,208	9,664	66,984
Foreign	265,492	2,551	2,844	42,408	6,917	1,410	10,006	4,560	3,581	24,181	75,332	23,419	24,752	14,325	5,413	23,793
West Germany	67,122	345	798	12,361	1,272	264	2,281	931	719	5,724	20,031	5,510	5,030	4,079	1,569	6,208
Japan	44,761	929	467	7,573	1,477	147	1,659	759	741	2,939	9,756	4,269	6,302	1,662	729	5,352
United Kingdom ...	43,710	270	569	5,560	721	369	1,826	909	557	4,488	12,578	3,991	4,319	2,924	1,338	3,291
France	27,389	171	242	3,949	835	131	1,086	529	349	2,539	7,428	2,481	2,767	2,019	815	2,048
Switzerland ...	16,156	106	283	4,468	851	28	448	159	136	1,227	4,195	1,330	778	546	85	1,516
Canada	14,652	158	88	1,479	251	169	706	283	281	1,997	4,789	1,213	1,159	906	196	977
Sweden	10,005	74	56	538	156	22	*459	*235	*186	*1,372	3,674	908	685	*620	*169	851
Netherlands ..	8,677	*138	64	1,372	215	*121	275	123	71	676	2,054	1,018	*1,719	222	68	541
Italy	8,564	69	*95	*1,921	*344	31	354	121	82	694	2,586	719	492	408	*137	511
Belgium	3,263	24	34	604	67	18	116	122	54	254	807	178	277	93	16	599
U.S.S.R.	3,117	21	12	312	34	28	41	54	72	192	1,262	471	229	82	39	268
Austria	2,757	23	15	240	47	11	115	51	82	329	1,080	185	191	103	40	245
Australia	2,286	28	26	272	31	8	109	51	50	301	804	147	119	107	30	203
Denmark	1,908	38	21	192	65	7	101	46	6	264	631	193	116	35	15	178
Mexico	1,162	20	4	394	335	2	28	8	14	77	162	28	12	27	9	42
Other foreign .	9,963	137	70	1,173	216	54	402	179	181	1,108	3,495	778	557	492	158	963

Columns I–XV: Product field.

[1] Countries selected on the basis of being in the top 10 of at least one of the Standard Industrial Classifications.
* Indicates ranking in the top six of this particular product field.

I Food and kindred products
II Textile mill products
III Chemicals, except drugs
IV Drugs
V Petroleum and gas extraction and petroleum refining
VI Rubber and miscellaneous plastics
VII Stone, clay, glass, and concrete products
VIII Primary metals
IX Fabricated metals
X Nonelectrical machinery
XI Electrical equipment except communication equipment
XII Communication equipment and electronic components
XIII Motor vehicles and other transportation equipment except aircraft
XIV Aircraft and parts
XV Professional and scientific instruments

SOURCE: Compiled from information in Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *U.S. Patent Activity in Fifty-two Standard Industrial Classification Categories, 1963-1975, 1976* (A study commissioned specifically for this report).

See Figure 1-18 in text.

Table 1-17. Major technological innovations by selected countries, 1953-73[1]

Period	United States	United Kingdom	West Germany	Japan	France	Five-nation total
			Percentage of total			
1953-55	76	13	6	—	5	100
1956-58	80	11	4	—	4	100
1959-61	69	19	2	2	8	100
1962-64	66	18	5	11	0	100
1965-67	54	24	12	7	3	100
1968-70	56	20	7	14	4	100
1971-73	59	15	9	10	8	100
			Number of innovations			
1953-55	63	11	5	—	4	83
1956-58	37	5	2	—	2	46
1959-61	36	10	1	1	4	52
1962-64	54	15	4	9	—	82
1965-67	37	16	8	5	2	68
1968-70	45	16	6	11	3	81
1971-73	47	12	7	8	6	80
Total	319	85	33	34	21	492

[1] By year of market introduction.

NOTE: Detail may not add to totals because of rounding.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1976, Appendix B.

See Figure 1-20 in text.

Table 1-18. U.S. international transactions in royalties and fees[1], 1966-75

[Dollars in millions]

Year	Direct investment-related			Unaffiliated		
	Balance	Receipts[2]	Payments[3]	Balance	Receipts	Payments
1966	$1,098	$1,162	$64	$277	$353	$76
1967	1,292	1,354	62	289	393	104
1968	1,350	1,430	80	331	437	106
1969	1,432	1,533	101	366	486	120
1970	1,647	1,758	111	459	573	114
1971	1,809	1,927	118	495	618	123
1972	1,860	2,115	155	516	655	139
1973	2,304	2,513	209	536	712	176
1974	2,859	3,071	212	565	751	186
1975(prel.)	3,285	3,526	241	567	759	192

[1] Represents total receipts and payments for the use of intangible property such as patents, licenses, management fees, etc. Excludes film rental receipts.
[2] Direct investment-related receipts measure the net transactions between U.S. firms and their foreign affiliates.
[3] Direct investment-related payments measure the net transactions between U.S.-based foreign affiliates and their foreign parents.

NOTE: Detail may not add to totals because of rounding.

SOURCE: Department of Commerce, *Survey of Current Business,* June 1975, and June 1976.

See Figure 1-22 in text.

Table 1-19. U.S. receipts and payments of royalties and fees for unaffiliated[1] foreign residents, 1966-75

[U.S. dollars in millions]

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975 (prel.)
Net receipts										
Total	$353	$393	$437	$486	$573	$618	$655	$712	$751	$759
Developed countries	304	342	375	426	505	547	575	633	646	644
Western Europe	186	190	196	222	247	268	270	297	321	343
Canada	30	33	31	28	33	32	38	32	38	37
Japan	70	95	130	155	202	223	240	273	249	227
Other developed countries[2]	18	24	18	21	23	24	27	31	38	37
Developing countries	50	50	59	59	64	62	72	74	94	105
Eastern Europe	—	1	4	2	4	9	8	5	11	9
Net payments										
Total	76	104	106	120	114	123	139	176	186	192
Developed countries	72	100	102	116	107	119	134	166	176	184
Western Europe	67	93	94	107	99	110	121	146	156	168
Canada	2	3	4	4	4	5	6	6	7	7
Japan	3	4	4	4	4	4	6	13	12	8
Developing countries	4	3	4	5	7	4	5	9	8	7
Eastern Europe	—	—	—	—	—	—	1	1	2	1

[1] Represents receipts and payments between U.S. residents with residents or governments of foreign countries for the use of intangible property such as patents, copyrights, or manufacturing rights. Excludes fees and royalties related to U.S. foreign direct investments. Excludes film rentals.

[2] Other developed countries included here are Australia, New Zealand, and the Republic of South Africa.

NOTE: Detail may not add to totals because of rounding.

SOURCE: Department of Commerce, Bureau of Economic Analysis tabulations, June 1975, and *Survey of Current Business,* June 1976.

See Figure 1-23 in text.

Table 1-20. U.S. receipts and payments of royalties and fees for direct investment abroad, 1966-75

[U.S. dollars in millions]

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975 (prel.)
Net receipts[1]										
Total	$1,162	$1,354	$1,431	$1,533	$1,758	$1,927	$2,115	$2,513	$3,071	$3,526
Developed countries	854	982	1,027	1,101	1,289	1,429	1,609	1,949	2,389	2,740
Western Europe	496	579	594	651	755	848	971	1,180	1,428	1,722
Canada	246	266	285	287	336	355	377	416	541	566
Japan	43	55	59	66	80	96	114	170	211	231
Other developed countries[2]	69	83	88	97	118	131	147	183	209	221
Developing countries	279	352	377	398	428	452	453	519	631	734
International and unallocated	29	20	27	34	40	46	53	46	51	52
Net payments[3]										
Total	64	62	80	101	111	118	155	209	212	241
Canada	41	43	47	56	62	64	60	73	83	89
United Kingdom	12	11	21	25	19	11	15	20	16	10
Other European countries	10	8	9	16	23	39	78	113	111	140
Other countries	1	1	3	4	7	4	2	2	2	1

[1] Represents net receipts of payments by U.S. firms from their foreign affiliates for the use of intangible property such as patents, techniques, processes, formulas, designs, trademarks, copyrights, franchises, manufacturing rights, management fees, etc.

[2] Other developed countries included here are Australia, New Zealand, and the Republic of South Africa.

[3] Payments measure net transactions between U.S. affiliates and their foreign patents. Affiliated payments are not further detailed because in many cases the amounts are too small or would disclose individual company data.

NOTE: Detail may not add to totals because of rounding.

SOURCE: Department of Commerce, Bureau of Economic Analyses, *Revised Data Series on U.S. Direct Investment Abroad, 1966-74,* 1976, *Survey of Current Business,* June 1976, and unpublished data.

See Figure 1-24 in text.

Table 1-21. Real Gross Domestic Product per employed civilian, for selected countries compared with the United States, 1960-76[1]

[Index, United States = 100]

Year	United States	France	West Germany	Japan	United Kingdom	Canada
1960	100	55.0	51.3	24.7	49.9	86.6
1965	100	61.3	55.2	32.2	48.2	85.6
1967	100	63.1	56.3	36.7	49.0	83.4
1970	100	71.4	67.0	48.7	52.6	88.6
1971	100	72.9	67.2	50.9	53.7	90.3
1972	100	74.5	67.9	54.0	53.5	90.2
1973	100	76.1	69.8	56.5	54.4	90.1
1974	100	80.5	73.9	58.1	56.1	92.1
1975	100	80.7	74.3	59.8	55.8	91.1
1976(est.)	100	82.6	77.3	61.1	55.5	90.6

[1] Output based on international price weights to enable comparable cross-country comparisons.

SOURCE: Department of Labor, Bureau of Labor Statistics, Office of Productivity and Technology, *Comparative Real Gross Domestic Product, Real GDP per Capita, and Real GDP per Employed Civilian, Six Countries,* May 1977, unpublished.

See Figure 1-25 in text.

Table 1-22. Relative productivity[1] in manufacturing industries by selected countries, 1960-76

[Index, 1967 = 100]

Year	United States	France	West Germany	Japan	United Kingdom	Canada
1960	78.8	68.7	66.4	52.6	76.8	75.5
1961	80.7	71.9	70.0	59.3	77.4	79.6
1962	84.5	75.2	74.4	61.9	79.3	83.9
1963	90.4	79.7	78.4	67.1	83.6	87.1
1964	95.2	83.7	84.5	75.9	89.7	90.9
1965	98.2	88.5	90.4	79.1	92.4	94.4
1966	99.7	94.7	94.0	87.1	95.7	97.2
1967	100.0	100.0	100.0	100.0	100.0	100.0
1968	103.6	111.4	107.6	112.6	106.9	107.3
1969	104.9	115.4	113.8	130.0	108.4	113.3
1970	104.5	121.2	116.6	146.5	109.1	115.2
1971	110.3	127.5	122.5	151.7	114.3	122.9
1972	116.0	135.9	130.3	163.9	121.2	127.4
1973	119.4	142.2	138.6	184.3	128.1	132.2
1974	114.7	146.1	145.6	187.5	127.9	132.3
1975	114.9	139.8	150.4	181.7	123.9	134.4
1976(est.)	122.4	153.6	162.4	204.6	125.4	137.4

[1] Output per man-hour.

SOURCE: Department of Labor, Bureau of Labor Statistics, Office of Productivity and Technology, "Output per Hour, Hourly Compensation, and Unit Labor Costs in Manufacturing, Twelve Countries, 1950-1975", 1977, unpublished. Estimates for 1976 are from the *International Economic Report of the President*, Council on International Economic Policy, Executive Office of the President, 1977, p. 144, and unpublished data.

See Figure 1-26 in text.

Table 1-23. U.S. trade balance[1] in R&D-intensive and non-R&D-intensive manufactured product groups, 1960-76

[Dollars in millions]

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
R&D-intensive																	
Balance	$5,891	$6,237	$6,720	$6,958	$7,970	$8,148	$7,996	$8,817	$9,775	$10,471	$11,722	$11,727	$11,012	$15,101	$23,875	$29,344	$28,973
Export	7,597	8,018	8,715	8,975	10,267	11,078	12,174	13,407	15,312	16,955	19,274	20,228	22,003	29,088	41,111	46,439	50,839
Import	1,706	1,781	1,995	2,017	2,297	2,930	4,178	4,590	5,537	6,484	7,552	8,501	10,991	13,987	17,236	17,095	21,866
Non-R&D-intensive																	
Balance	-179	-12	-691	-765	-678	-2,027	-3,325	-3,729	-6,581	-6,698	-8,285	-11,698	-15,039	-15,370	-15,575	-9,474	-16,503
Export	4,962	4,730	4,940	5,284	6,121	6,281	6,913	7,437	8,506	9,830	10,069	10,215	11,737	15,643	22,412	24,511	26,406
Import	5,141	4,742	5,631	6,049	6,799	8,308	10,238	11,166	15,087	16,528	18,354	21,913	26,776	31,013	37,987	33,985	42,909

[1] Exports less imports.

SOURCE: Department of Commerce, Domestic and International Business Administration, *Overseas Business Reports*, August 1967, April 1972, and April 1977.

See Figure 1-28 in text.

Table 1-24. U.S. trade balance[1] in selected R&D-intensive manufactured product groups, 1960-76

[Dollars in millions]

Product groups	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Chemicals[2]																	
Balance	$955	$1,051	$1,104	$1,294	$1,662	$1,634	$1,718	$1,844	$2,158	$2,155	$2,376	$2,224	$2,118	$3,286	$4,801	$4,995	$5,186
Export	1,776	1,789	1,876	2,009	2,364	2,403	2,675	2,802	3,287	3,383	3,826	3,836	4,133	5,749	8,819	8,691	9,958
Import	821	738	772	715	702	769	957	958	1,129	1,228	1,450	1,612	2,015	2,463	4,018	3,696	4,772
Nonelectrical machinery																	
Balance	2,948	3,288	3,547	3,574	3,989	4,115	4,101	4,218	4,280	4,838	5,583	5,268	5,325	6,904	10,828	14,574	14,812
Export	3,386	3,743	4,087	4,209	4,860	5,275	5,778	6,181	6,560	7,460	8,686	8,772	9,864	12,556	17,298	21,633	22,833
Import	438	455	540	635	871	1,160	1,677	1,963	2,280	2,622	3,103	3,504	4,539	5,652	6,470	7,059	8,021
Electrical machinery[3]																	
Balance	804	891	946	1,074	1,222	1,020	890	962	792	729	728	512	321	533	1,680	2,671	1,854
Export	1,090	1,225	1,361	1,493	1,665	1,660	1,900	2,098	2,284	2,677	2,999	3,067	3,698	5,032	7,019	7,582	9,278
Import	286	334	415	419	443	640	1,010	1,136	1,492	1,948	2,271	2,555	3,377	4,499	5,339	4,911	7,424
Aircraft																	
Balance	970	766	857	726	791	990	824	1,271	2,015	2,140	2,382	3,049	2,580	3,556	5,258	5,617	5,682
Export	1,024	903	980	817	874	1,130	1,097	1,519	2,309	2,423	2,656	3,387	2,995	4,119	5,766	6,136	6,116
Import	54	137	123	91	83	140	273	248	294	283	274	338	415	563	508	519	434
Professional and scientific instruments																	
Balance	214	241	266	290	306	389	463	522	530	609	653	674	668	822	1,308	1,487	1,439
Export	321	358	411	447	504	610	724	807	872	1,012	1,107	1,166	1,313	1,632	2,209	2,397	2,654
Import	107	117	145	157	198	221	261	285	342	403	454	492	645	810	901	910	1,215

[1] Exports less imports.
[2] Includes drugs and other allied products.
[3] Includes communication equipment.

SOURCE: Department of Commerce, Domestic and International Business Administration, *Overseas Business Reports.* August 1967, April 1972, and April 1977.

See Figure 1-29 in text.

Table 1-25. U.S. trade balance[1] with selected nations for R&D-intensive manufactured products, 1966-76

[Dollars in millions]

Nations	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Developing nations[2]											
Balance	$3,441	$3,677	$4,430	$4,455	$4,928	$5,087	$5,277	$6,642	$10,656	$14,727	$16,052
Export	3,682	3,923	4,822	5,002	5,679	5,996	6,765	8,966	14,024	17,701	20,104
Import	241	246	392	547	751	909	1,488	2,324	3,368	2,974	4,052
Western Europe											
Balance	1,890	2,283	2,566	2,986	3,942	3,599	3,089	4,125	5,983	6,700	7,060
Export	3,865	4,359	5,020	5,655	6,927	6,861	7,345	9,596	12,622	13,540	14,048
Import	1,975	2,076	2,454	2,669	2,985	3,262	4,256	5,471	6,639	6,840	7,588
Canada											
Balance	1,800	1,760	1,719	1,914	1,684	1,865	2,333	3,001	4,242	4,833	4,732
Export	2,838	2,983	3,142	3,478	3,513	3,914	4,678	5,741	7,419	8,136	8,831
Import	1,038	1,223	1,423	1,564	1,829	2,049	2,345	2,740	3,177	3,303	4,099
Japan											
Balance	-133	-115	-200	-324	-224	-516	-971	-848	-550	-1,021	-2,654
Export	661	772	930	1,180	1,536	1,520	1,639	2,218	3,007	2,389	2,701
Import	794	887	1,130	1,504	1,760	2,036	2,610	3,066	3,557	3,410	5,355

[1] Exports less imports.
[2] Includes the Republic of South Africa in 1966 and 1967.

SOURCE: Department of Commerce, Domestic and International Business Administration, *Overseas Business Reports*, May 1972, June 1974, October 1976, and June 1977.

See Figure 1-31 in text.

Table 2-1. National R&D expenditures, 1960-76

[Dollars in billions]

Year	Current dollars	Constant 1972 dollars[1]
1960	$13.6	$19.7
1961	14.3	20.7
1962	15.4	21.9
1963	17.1	23.9
1964	18.9	26.0
1965	20.1	27.0
1966	21.9	28.5
1967	23.2	29.4
1968	24.7	29.9
1969	25.7	29.6
1970	26.0	28.5
1971	26.7	27.9
1972	28.4	28.4
1973	30.4	28.8
1974	32.3	27.8
1975(est.)	35.2	27.7
1976(est.)	38.1	28.5

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), p. 28.

See Figure 2-1 in text.

Table 2-2. Scientists and engineers[1] employed in R&D by sector, 1961-75

[In thousands]

Year	Total	Federal Government	Industry	Universities and colleges	FFRDC's[2]	Other nonprofit institutions
1961	425.7	51.1	312.0	42.4	9.1	11.1
1965	494.1	61.8	348.4	53.4	11.1	19.4
1968	550.4	68.1	381.9	66.0	11.2	23.2
1969	558.2	69.9	385.6	68.3	11.6	22.8
1970	549.6	69.8	375.5	68.5	11.5	24.3
1971	529.8	66.5	358.4	68.4	11.5	25.0
1972	521.9	65.2	353.3	66.5	11.7	25.2
1973	521.1	62.3	357.4	64.8	12.0	24.6
1974	527.2	65.0	357.9	66.7	12.1	25.5
1975(est.)	530.5	64.5	358,0	71.0	12.8	24.2

[1] Full-time-equivalent basis, excluding those employed in State and local agencies, calculated as the yearly average for the industry sector.
[2] Federally Funded Research and Development Centers administered by universities.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), p. 32.

See Figure 2-2 in text.

Table 2-3. National R&D expenditures as a percent of GNP by source, 1960-76

[Current dollars in billions]

Year	Gross National Product (GNP)	All sources: Total R&D	All sources: R&D as a percent of GNP	Federal sources: Total R&D	Federal sources: R&D as a percent of GNP	All other sources: Total R&D	All other sources: R&D as a percent of GNP
1960	$506.0	$13.6	2.69	$8.8	1.74	$4.8	0.95
1961	523.3	14.3	2.74	9.3	1.78	5.1	.97
1962	563.8	15.4	2.73	9.9	1.76	5.5	.98
1963	594.7	17.1	2.87	11.2	1.88	5.9	.99
1964	635.7	18.9	2.97	12.6	1.98	6.3	.99
1965	688.1	20.1	2.92	13.0	1.89	7.1	1.03
1966	753.0	21.9	2.91	14.0	1.86	7.9	1.05
1967	796.3	23.2	2.91	14.4	1.81	8.8	1.11
1968	868.5	24.7	2.84	15.0	1.73	9.7	1.12
1969	935.5	25.7	2.75	14.9	1.59	10.8	1.15
1970	982.4	26.0	2.65	14.8	1.51	11.3	1.15
1971	1,063.4	26.7	2.50	15.0	1.41	11.8	1.11
1972	1,171.1	28.4	2.43	15.9	1.36	12.5	1.07
1973	1,306.6	30.4	2.33	16.4	1.26	14.0	1.07
1974	1,413,2	32.3	2.29	16.9	1.20	15.4	1.09
1975(est.)	1,516.3	35.2	2.32	18.6	1.23	16.2	1.07
1976(est.)	1,691.6	38.1	2.25	20.1	1.19	18.0	1.06

NOTE: Percents are calculated from unrounded figures.
Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), p. 28; and Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business,* January 1976; and *Commerce News, March 21, 1977.*

See Figure 2-3 in text.

Table 2-4. National expenditures for R&D by source, 1960-76

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges[1]	Other nonprofit institutions
			Current dollars		
1960	$13,551	$8,752	$4,508	$149	$142
1961	14,346	9,264	4,749	165	168
1962	15,426	9,926	5,114	185	201
1963	17,093	11,219	5,449	207	218
1964	18,894	12,553	5,880	235	226
1965	20,091	13,033	6,539	267	252
1966	21,894	13,990	7,317	303	284
1967	23,205	14,420	8,134	345	306
1968	24,669	14,952	8,997	391	329
1969	25,686	14,914	9,998	420	354
1970	26,047	14,764	10,434	461	388
1971	26,745	14,982	10,817	529	417
1972	28,415	15,887	11,509	576	443
1973	30,417	16,437	12,896	613	471
1974	32,322	16,897	14,253	673	499
1975(est.)	35,209	18,577	15,335	746	551
1976(est.)	38,090	20,130	16,550	815	595
			Constant 1972 dollars[2]		
1960	$19,734	$12,745	$6,565	$217	$207
1961	20,707	13,372	6,855	238	242
1962	21,865	14,069	7,249	262	285
1963	23,876	15,671	7,611	289	305
1964	25,985	17,264	8,087	323	311
1965	27,033	17,536	8,798	359	339
1966	28,523	18,226	9,532	395	370
1967	29,366	18,249	10,294	437	387
1968	29,876	18,108	10,896	474	398
1969	29,619	17,198	11,529	484	408
1970	28,510	16,160	11,421	505	425
1971	27,854	15,603	11,265	551	434
1972	28,415	15,887	11,509	576	443
1973	28,750	15,536	12,189	579	445
1974	27,766	14,515	12,244	578	429
1975(est.)	27,669	14,599	12,051	586	433
1976(est.)	28,479	15,050	12,374	609	445

[1] Includes State and local sources which accounted for almost one-half of these expenditures since 1970.
[2] GNP implicit deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), p. 28.

See Figure 2-4 in text.

Table 2-5. National expenditures for R&D by performer, 1960-76

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges[1]	FFRDC's[2]	Other nonprofit institutions
	Current dollars					
1960	$13,551	$1,726	$10,509	$646	$360	$310
1961	14,346	1,874	10,908	763	410	391
1962	15,426	2,098	11,464	904	470	490
1963	17,093	2,279	12,630	1,081	530	573
1964	18,894	2,838	13,512	1,275	629	640
1965	20,091	3,093	14,185	1,474	629	710
1966	21,894	3,220	15,548	1,715	630	781
1967	23,205	3,396	16,385	1,921	673	830
1968	24,669	3,493	17,429	2,149	719	879
1969	25,686	3,503	18,308	2,220	725	930
1970	26,047	3,855	18,062	2,335	737	1,058
1971	26,745	4,156	18,311	2,500	716	1,062
1972	28,415	4,482	19,383	2,676	764	1,110
1973	30,417	4,619	20,921	2,940	817	1,120
1974	32,322	4,815	22,369	3,021	865	1,252
1975(est.)	35,209	5,302	24,250	3,395	987	1,275
1976(est.)	38,090	5,600	26,500	3,660	1,080	1,250
	Constant 1972 dollars[3]					
1960	$19,734	$2,513	$15,304	$941	$524	$451
1961	20,707	2,705	15,745	1,101	592	564
1962	21,865	2,974	16,249	1,281	666	695
1963	23,876	3,183	17,642	1,510	740	800
1964	25,985	3,903	18,583	1,754	865	880
1965	27,033	4,162	19,086	1,983	846	955
1966	28,523	4,195	20,255	2,234	821	1,017
1967	29,366	4,298	20,735	2,431	852	1,050
1968	29,876	4,230	21,108	2,603	871	1,065
1969	29,619	4,039	21,112	2,560	836	1,072
1970	28,510	4,220	19,770	2,556	807	1,158
1971	27,854	4,328	19,070	2,604	746	1,106
1972	28,415	4,482	19,383	2,676	764	1,110
1973	28,750	4,366	19,774	2,779	772	1,059
1974	27,766	4,136	19,216	2,595	743	1,076
1975(est.)	27,669	4,167	19,057	2,668	776	1,002
1976(est.)	28,479	4,187	19,813	2,736	807	935

[1] Includes State and local sources.
[2] Federally Funded Research and Development Centers administered by universities.
[3] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), pp. 20-21.

See Figure 2-5 in text.

Table 2-6. National R&D expenditures by character of work, 1960-76

[Dollars in millions]

Year	Current dollars			Constant 1972 dollars[1]		
	Basic research	Applied research	Development	Basic research	Applied research	Development
1960	$1,183	$3,057	$9,311	$1,723	$4,452	$13,559
1961	1,378	3,115	9,853	1,989	4,496	14,222
1962	1,695	3,727	10,004	2,403	5,283	14,180
1963	1,974	3,825	11,294	2,757	5,343	15,776
1964	2,301	4,238	12,355	3,165	5,829	16,992
1965	2,572	4,470	13,049	3,461	6,015	17,558
1966	2,825	4,747	14,322	3,680	6,184	18,658
1967	3,029	4,968	15,208	3,833	6,287	19,246
1968	3,286	5,356	16,027	3,980	6,487	19,410
1969	3,378	5,533	16,775	3,895	6,380	19,344
1970	3,521	5,919	16,607	3,854	6,479	18,178
1971	3,515	6,076	17,154	3,661	6,328	17,865
1972	3,702	6,276	18,437	3,702	6,276	18,437
1973	3,816	6,829	19,772	3,607	6,455	18,688
1974	4,072	7,515	20,735	3,498	6,456	17,812
1975(est.)	4,446	8,275	22,488	3,494	6,503	17,672
1976(est.)	4,750	8,925	24,415	3,551	6,673	18,254

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), pp. 29-31.

See Figure 2-6 in text.

Table 2-7. Basic research expenditures by source, 1960-76

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges	Other nonprofit institutions
	Current dollars				
1960	$1,183	$693	$331	$72	$87
1961	1,378	841	350	85	102
1962	1,695	1,091	382	102	120
1963	1,974	1,310	414	121	129
1964	2,301	1,595	424	144	138
1965	2,572	1,817	448	164	143
1966	2,825	1,986	496	196	147
1967	3,029	2,173	477	223	156
1968	3,286	2,327	518	276	165
1969	3,378	2,386	519	298	175
1970	3,521	2,469	509	350	193
1971	3,515	2,379	527	400	209
1972	3,702	2,525	528	428	221
1973	3,816	2,607	573	418	218
1974	4,072	2,788	615	430	239
1975(est.)	4,446	3,029	670	476	271
1976(est.)	4,750	3,210	715	525	300
	Constant 1972 dollars[1]				
1960	$1,723	$1,009	$482	$105	$127
1961	1,989	1,214	505	123	147
1962	2,403	1,546	541	145	170
1963	2,757	1,830	578	169	180
1964	3,165	2,194	583	198	190
1965	3,461	2,445	603	221	192
1966	3,680	2,587	646	255	192
1967	3,833	2,750	604	282	197
1968	3,980	2,818	627	334	200
1969	3,895	2,751	598	344	202
1970	3,854	2,702	557	383	211
1971	3,661	2,478	549	417	218
1972	3,702	2,525	528	428	221
1973	3,607	2,464	542	395	206
1974	3,498	2,395	528	369	205
1975(est.)	3,494	2,380	527	374	213
1976(est.)	3,551	2,400	535	393	224

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), p. 29.

See Figure 2-7 in text.

Table 2-8. Applied research expenditures by source, 1960-76

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges	Other nonprofit institutions
			Current dollars		
1960	$3,057	$1,725	$1,228	$66	$38
1961	3,115	1,804	1,197	69	45
1962	3,727	2,127	1,473	70	57
1963	3,825	2,205	1,487	72	61
1964	4,238	2,503	1,596	77	62
1965	4,470	2,653	1,658	88	71
1966	4,747	2,729	1,844	89	85
1967	4,968	2,874	1,895	102	97
1968	5,356	3,020	2,132	97	107
1969	5,533	2,982	2,327	105	119
1970	5,919	3,258	2,433	98	130
1971	6,076	3,313	2,505	115	143
1972	6,276	3,393	2,599	132	152
1973	6,829	3,650	2,836	166	177
1974	7,515	3,988	3,139	206	182
1975(est.)	8,275	4,458	3,389	231	197
1976(est.)	8,925	4,825	3,645	250	205
			Constant 1972 dollars[1]		
1960	$4,452	$2,512	$1,788	$96	$55
1961	4,496	2,604	1,728	100	65
1962	5,283	3,015	2,088	99	81
1963	5,343	3,080	2,077	101	85
1964	5,829	3,442	2,195	106	85
1965	6,015	3,570	2,231	118	96
1966	6,184	3,555	2,402	116	111
1967	6,287	3,637	2,398	129	123
1968	6,487	3,658	2,582	117	130
1969	6,380	3,439	2,683	121	137
1970	6,479	3,566	2,663	107	142
1971	6,328	3,450	2,609	120	149
1972	6,276	3,393	2,599	132	152
1973	6,455	3,450	2,681	157	167
1974	6,456	3,426	2,697	177	156
1975(est.)	6,503	3,503	2,663	182	155
1976(est.)	6,673	3,607	2,725	187	153

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), p. 30.

See Figure 2-7 in text.

Table 2-9. Development expenditures by source, 1960-76

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges	Other nonprofit institutions
	Current dollars				
1960	$9,311	$6,334	$2,949	$11	$17
1961	9,853	6,619	3,202	11	21
1962	10,004	6,708	3,259	13	24
1963	11,294	7,704	3,548	14	28
1964	12,355	8,455	3,860	14	26
1965	13,049	8,563	4,433	15	38
1966	14,322	9,275	4,977	18	52
1967	15,208	9,373	5,762	20	53
1968	16,027	9,606	6,347	17	57
1969	16,775	9,546	7,152	17	60
1970	16,607	9,037	7,492	13	65
1971	17,154	9,290	7,785	14	65
1972	18,437	9,959	8,392	16	70
1973	19,772	10,180	9,487	29	76
1974	20,735	10,120	10,500	37	78
1975(est.)	22,488	11,090	11,276	39	83
1976(est.)	24,415	12,095	12,190	40	90
	Constant 1972 dollars[1]				
1960	$13,559	$9,224	$4,294	$16	$25
1961	14,222	9,554	4,622	16	30
1962	14,180	9,508	4,619	18	34
1963	15,776	10,761	4,956	20	39
1964	16,992	11,628	5,309	19	36
1965	17,558	11,522	5,965	20	51
1966	18,658	12,083	6,484	23	68
1967	19,246	11,862	7,292	25	67
1968	19,410	11,634	7,687	21	69
1969	19,344	11,008	8,247	20	69
1970	18,178	9,892	8,201	14	71
1971	17,865	9,675	8,108	15	68
1972	18,437	9,959	8,392	16	70
1973	18,688	9,622	8,967	27	72
1974	17,812	8,693	9,020	32	67
1975(est.)	17,672	8,715	8,861	31	65
1976(est.)	18,254	9,043	9,114	30	67

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), p. 31.

See Figure 2-7 in text.

Table 2-10. Federal expenditures for R&D and R&D plant, as a percent of total Federal outlays, and as a percent of the relatively controllable portion of the Federal outlays, 1960-76

[Dollars in billions]

Year	Total Federal outlays	Total Federal R&D and R&D plant expenditures[1]	Expenditures for R&D & R&D plant as a percent of total Federal outlays	Expenditures for R&D & R&D plant as a percent of controllable Federal outlays
1960	$92.2	$7.7	8.4	NA
1961	97.8	9.3	9.5	NA
1962	106.8	10.4	9.7	NA
1963	111.3	12.0	10.8	NA
1964	118.6	14.7	12.4	NA
1965	118.4	14.9	12.6	NA
1966	134.7	16.0	11.9	NA
1967	158.3	16.9	10.7	16.3
1968	178.8	17.0	9.5	14.7
1969	184.5	16.3	8.9	14.6
1970	196.6	15.7	8.0	13.7
1971	211.4	16.0	7.6	14.0
1972	231.9	16.7	7.2	13.9
1973	246.5	17.5	7.1	15.1
1974	268.4	18.3	6.8	15.1
1975	324.6	19.6	6.0	13.8
1976(est.)	373.5	21.4	5.7	13.5

[1]Reported by Federal agencies.

NOTE: NA = not available.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977,* Vol. XXV (NSF 77-301), pp. 4-5, and earlier volumes.

See Figure 2-8 in text.

Table 2-11. Federal obligations for R&D by function, 1969-76

[Dollars in millions]

Function	1969	1970	1971	1972	1973	1974	1975	1976 (est.)
	Current dollars							
Total	$15,641	$15,340	$15,564	$16,512	$16,821	$17,438	$19,044	$21,625
National Defense	8,354	7,976	8,106	8,898	8,998	8,975	9,621	10,641
Space	3,732	3,510	2,893	2,714	2,601	2,478	2,511	2,879
All civilian R&D	3,556	3,854	4,565	4,900	5,222	5,986	6,912	8,105
Health	1,127	1,126	1,340	1,590	1,626	2,098	2,178	2,368
Energy development and conversion	328	317	324	383	442	605	1,110	1,632
Science and technology base[1]	513	525	524	601	604	694	781	857
Environment	315	354	465	533	652	693	837	975
Transportation and communications	458	590	779	615	630	703	641	711
Natural resources	201	238	326	354	341	341	439	504
Food and fiber	225	241	247	291	297	291	349	402
Education	155	147	186	191	214	173	161	188

(Continued)

Table 2-11. (Continued)

Function	1969	1970	1971	1972	1973	1974	1975	1976 (est.)
	Current dollars							
Income security and social services	97	106	132	129	162	137	151	154
Area and community development, housing, and public services	49	91	108	101	118	120	127	137
Economic growth and productivity	56	79	93	58	68	68	63	79
Crime prevention and control	5	9	10	25	35	36	46	63
International cooperation and development	27	32	32	29	33	27	30	34
	Constant 1972 dollars[2]							
Total	$18,036	$16,791	$16,209	$16,512	$15,899	$14,980	$14,966	$16,168
National defense	9,633	8,731	8,442	8,898	8,505	7,710	7,561	7,956
Space	4,303	3,842	3,013	2,714	2,458	2,129	1,973	2,153
All civilian R&D	4,100	4,219	4,754	4,900	4,936	5,142	5,432	6,060
Health	1,299	1,232	1,396	1,590	1,537	1,802	1,712	1,770
Energy development and conversion	378	347	337	383	418	520	872	1,220
Science and technology base[1]	592	574	545	601	571	596	614	641
Environment	363	388	484	533	616	595	658	729
Transportation and communications	528	646	811	614	595	604	504	532
Natural resources	232	260	339	354	322	293	345	377
Food and fiber	259	263	257	291	281	250	274	301
Education	178	160	194	191	202	149	127	141
Income security and social services	111	116	138	129	153	118	119	115
Area and community development, housing, and public services	57	100	112	101	112	103	100	102
Economic growth and productivity	64	87	96	58	64	58	50	59
Crime prevention and control	6	9	11	25	33	31	36	47
International cooperation and development	31	35	34	29	31	23	24	25

[1] Basic research obligations which can be associated with the agencies' missions are not included here but are distributed across the appropriate functions.
[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.
Function categories are not the same as those of Appendix Table 1-3; e.g., "Advancement of Knowledge" does not equal "Science and Technology Base".

SOURCE: National Science Foundation, *An Analysis of Federal R&D Funding by Function, 1969-77* (NSF 76-325), p. 5.

See Figures 2-9 and 2-10 and Table 2-11 in text.

Table 2-12. Federal expenditures for R&D plant, 1960-75

[Dollars in millions]

Year	Current dollars	Constant 1972 dollars[1]
1960	$443.8	$646.3
1961	539.1	778.1
1962	779.1	1,104.3
1963	673.6	940.9
1964	948.1	1,303.9
1965	1,077.4	1,449.7
1966	1,047.8	1,365.0
1967	786.1	994.8
1968	715.9	867.0
1969	652.2	752.1
1970	578.9	633.6
1971	612.7	638.1
1972	564.4	564.4
1973	638.0	603.0
1974	704.2	604.9
1975	829.7	652.0

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977,* Vol. XXV, Detailed Statistical Tables (NSF 76-315), p. 93, and earlier volumes.

See Figure 2-12 in text.

Table 2-13. Federal obligations for R&D plant by performer, 1962-75

[Dollars in millions]

Year	Total	Federal intramural	Industry	Universities and colleges	FFRDC's[1]	Nonprofit institutions
	Current dollars					
1962	$779.1	NA	NA	NA	NA	NA
1963	1,168.3	NA	NA	NA	NA	NA
1964	1,098.5	NA	NA	NA	NA	NA
1965	1,131.6	$913.0	NA	$141.6	$50.2	NA
1966	853.3	629.0	NA	162.9	31.1	NA
1967	620.1	239.0	NA	111.7	138.8	NA
1968	603.8	294.2	$81.7	98.1	101.7	$20.9
1969	669.0	260.4	141.7	61.9	176.6	25.8
1970	524.4	166.0	102.3	56.1	169.0	28.8
1971	611.2	200.0	167.4	49.2	178.7	5.8
1972	602.1	246.6	142.4	45.3	130.4	30.0
1973	774.3	323.8	221.8	42.6	162.3	18.8
1974	766.3	308.7	294.1	25.0	118.4	8.3
1975	820.7	346.8	291.9	35.9	131.8	14.1
	Constant 1972 dollars[2]					
1962	$1,104.3	NA	NA	NA	NA	NA
1963	1,631.9	NA	NA	NA	NA	NA
1964	1,510.8	NA	NA	NA	NA	NA
1965	1,522.6	$1,228.5	NA	$190.5	$67.5	NA
1966	1,118.2	819.4	NA	212.2	40.5	NA
1967	784.7	302.5	NA	141.4	175.7	NA
1968	731.3	356.3	$98.9	118.8	123.2	$25.3
1969	771.4	300.3	163.4	71.4	203.6	29.8
1970	574.0	181.7	112.0	61.4	185.0	31.5
1971	636.5	208.3	174.3	51.2	186.1	6.0
1972	602.1	246.6	142.4	45.3	130.4	30.0
1973	731.9	306.0	209.6	40.3	153.4	17.8
1974	658.3	265.2	252.6	21.5	101.7	7.1
1975	645.0	272.5	229.4	28.2	103.6	11.1

[1] Federally Funded Research and Development Centers administered by universities.
[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: NA = not available. Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977*, Vol. XXV, Detailed Statistical Tables (NSF 76-315), pp. 94-95, and earlier volumes.

See Figure 2-13 in text.

Table 2-14. Federal obligations for R&D plant as a percent of Federal obligations for total R&D including plant, by performer, 1962-75

Year	Total	Federal intramural	Industry	Universities and colleges	FFRDC's[1]	Nonprofit institutions
	Percent					
1962	7	NA	NA	NA	NA	NA
1963	9	NA	NA	NA	NA	NA
1964	7	NA	NA	NA	NA	NA
1965	7	23	NA	11	8	NA
1966	5	16	NA	11	5	NA
1967	4	7	NA	7	17	NA
1968	4	8	1	6	12	3
1969	4	7	2	4	20	4
1970	3	4	1	4	18	4
1971	4	5	2	3	20	1
1972	4	5	2	2	15	4
1973	4	7	3	2	18	2
1974	4	6	3	1	13	1
1975	4	6	3	1	12	1
	Federal obligations for R&D plant (dollars in millions)					
1962	$779.1	NA	NA	NA	NA	NA
1963	1,168.3	NA	NA	NA	NA	NA
1964	1.098.5	NA	NA	NA	NA	NA
1965	1,131.6	$913.0	NA	$141.6	$50.2	NA
1966	858.3	629.0	NA	162.9	31.1	NA
1967	620.1	239.0	NA	111.7	138.8	NA
1968	603.8	294.2	$81.7	98.1	101.7	$20.9
1969	669.0	260.4	141.7	61.9	176.6	25.8
1970	524.4	166.0	102.3	56.1	169.0	28.8
1971	611.2	200.0	167.4	49.2	178.7	5.8
1972	602.1	246.6	142.4	45.3	130.4	30.0
1973	774.3	323.8	221.8	42.6	162.3	18.8
1974	766.3	308.7	294.1	25.0	118.4	8.3
1975	820.7	346.8	291.9	35.9	131.8	14.1
	Federal obligations for total R&D including plant (dollars in millions)					
1962	$11,065.7	$2,841.8	NA	NA	NA	NA
1963	13,650.3	3,378.2	NA	NA	NA	NA
1964	15,310.4	3,802.2	NA	$1,158.9	$579.5	NA
1965	15,731.2	4,005.7	NA	1,329.7	599.3	NA
1966	16,162.4	4,025.6	NA	1,489.6	671.3	NA
1967	17,149.4	3,634.8	NA	1,566.2	805.3	NA
1968	16,525.3	3,787.4	$9,541.7	1,588.4	815.6	$640.3
1969	16,306.2	3,758.8	9,266.3	1,597.9	899.0	634.7
1970	15,854.3	4,041.5	8,483.6	1,529.0	918.7	740.3
1971	16,160.8	4,365.6	8,278.1	1,693.7	907.6	701.6
1972	17,154.7	4,742.4	8,523.9	1,947.5	891.0	776.2
1973	17,595.6	4,942.8	8,678.3	1,958.1	887.6	802.6
1974	18,204.5	5,123.5	8,732.1	2,239.5	907.5	910.5
1975	19,865.0	5,741.7	9,405.9	2,438.6	1,066.9	951.8

[1] Federally Funded Research and Development Centers administered by universities.

NOTE: NA = not available. Detail may not add to totals because of the omission of State and local governments and foreign performers.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977*, Vol. XXV, Detailed Statistical Tables (NSF 76-315), p. 1, and earlier volumes.

See Figure 2-14 in text.

Table 2-15. Federal obligations for scientific and technical information activities compared with total Federal R&D obligations, 1960-76

Year	Obligations for scientific and technical information activities (in millions)		Ratio of these obligations to total Federal R&D obligations
	Current dollars	Constant 1972 dollars[1]	
1960	$76	$110	.010
1961	92	132	.010
1962	129	182	.013
1963	165	230	.013
1964	203	279	.014
1965	225	302	.015
1966	278	362	.018
1967	324	411	.020
1968	359	435	.023
1969	362	418	.023
1970	387	423	.025
1971	398	414	.026
1972	419	419	.025
1973	438	414	.026
1974	443	381	.025
1975	398	313	.021
1976(est.)	430	321	.020

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977,* Vol. XXV, Detailed Statistical Tables, (NSF 76-315), p. 153, and earlier volumes.

See Figure 2-15 in text.

Table 2-16. Federal obligations for scientific and technical information activities by agency, 1960-76

[Dollars in millions]

Year	Total	DOD	HEW	Commerce	Library of Congress	NASA	Interior	NSF	USDA	Other agencies
					Current dollars					
1960	$76	$16	$10	$23	$5	$1	$4	$7	$4	$6
1961	92	23	12	27	6	3	4	7	4	6
1962	129	38	24	28	6	7	5	10	4	7
1963	165	53	27	31	8	14	7	10	4	11
1964	203	84	24	33	9	20	8	12	5	8
1965	225	99	24	37	10	19	9	13	6	8
1966	278	119	37	42	13	23	10	16	6	12
1967	324	139	53	46	13	24	12	12	14	11
1968	359	155	60	47	17	27	14	16	8	15
1969	362	147	65	52	20	28	13	12	9	16
1970	387	145	66	60	22	27	13	15	10	29
1971	398	141	73	69	25	27	14	14	10	25
1972	419	150	68	78	30	27	14	12	11	29
1973	438	161	67	85	32	25	16	11	13	28
1974	443	151	77	89	29	23	20	10	13	31
1975	398	87	80	96	31	24	25	7	14	34
1976(est.)	430	96	78	108	33	25	30	8	17	36
					Constant 1972 dollars[1]					
1960	$110	$23	$15	$33	$7	$1	$6	$10	$6	$9
1961	132	33	17	39	9	4	6	10	6	9
1962	182	64	34	40	9	10	7	14	6	10
1963	230	74	38	43	11	20	10	14	6	15
1964	279	116	33	45	12	28	11	17	7	11
1965	302	133	32	50	13	26	12	17	8	11
1966	362	155	48	55	17	30	13	21	8	16
1967	411	176	67	58	16	30	15	15	18	14
1968	435	188	73	57	21	33	17	19	10	18
1969	418	170	75	60	23	32	15	14	10	18
1970	423	159	72	66	24	30	14	16	11	32
1971	414	147	76	72	26	28	15	15	10	26
1972	419	150	68	78	30	27	14	12	11	29
1973	414	152	63	80	30	24	15	10	12	26
1974	381	130	66	76	25	20	17	9	11	27
1975	313	68	63	75	24	19	20	6	11	27
1976(est.)	321	72	58	81	25	19	22	6	13	27

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977,* Vol. XXV Detailed Statistical Tables (NSF 76-315), and earlier volumes.

See Figure 2-16 in text.

Table 2-17. Federal obligations for scientific and technical information activities by type of activity, 1960-76

[Dollars in millions]

Year	Total	Publication and distribution	Documentation, reference and information services	Symposia and audiovisual media	R&D in information sciences, documentation and information systems, techniques and devices
			Current dollars		
1960	$76	$37	$28	$8	$3
1961	92	49	29	7	7
1962	129	56	42	17	13
1963	165	68	64	21	12
1964	203	65	99	25	14
1965	225	68	102	32	22
1966	278	83	125	22	48
1967	324	87	153	32	53
1968	359	101	166	34	59
1969	362	96	171	32	64
1970	387	99	193	33	62
1971	398	106	194	33	65
1972	419	117	197	37	70
1973	438	123	198	38	79
1974	443	129	199	35	79
1975	398	123	179	24	72
1976(est.)	430	138	192	26	75
			Constant 1972 dollars[1]		
1960	$110	$54	$41	$11	$4
1961	132	70	42	10	10
1962	182	79	60	24	19
1963	230	95	89	29	17
1964	279	90	136	34	19
1965	302	92	137	43	30
1966	362	108	162	29	62
1967	411	110	193	40	67
1968	435	122	201	41	71
1969	418	111	197	37	73
1970	423	108	211	36	68
1971	414	110	202	34	68
1972	419	117	197	37	70
1973	414	116	187	36	75
1974	381	111	171	30	68
1975	313	97	141	19	57
1976(est.)	321	103	144	19	56

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977,* Vol. XXV Detailed Statistical Tables (NSF 76-315), pp. 156-157, and earlier volumes.

See Figure 2-17 in text.

Table 2-18. Scientific and technical articles published by U.S. authors in U.S. primary journals, 1960-75

Index: 1960 = 100

Year	Index
1960	100
1962	119
1964	162
1966	175
1968	199
1969	215
1970	224
1971	231
1972	239
1973	246
1974	248
1975(est.)	254

NOTE: Data for 1961, 1963, 1965, and 1967 are not available. Estimate is shown for 1975.

SOURCE: National Federation of Abstracting and Indexing Services, *Science Literature Indicators Study, 1975.*

See Figure 2-18 in text.

Table 3-1. Basic research expenditures, 1960-76

[Dollars in millions]

Year	Current dollars	Constant 1972 dollars
1960	$1,183	$1,723
1961	1,378	1,989
1962	1,695	2,403
1963	1,974	2,757
1964	2,301	3,165
1965	2,572	3,461
1966	2,825	3,680
1967	3,029	3,833
1968	3,286	3,980
1969	3,378	3,895
1970	3,521	3,854
1971	3,515	3,661
1972	3,702	3,702
1973	3,816	3,607
1974	4,072	3,498
1975 (est.)	4,446	3,494
1976 (est.)	4,750	3,551

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), pp. 22-23.

See Figure 3-1 in text.

Table 3-2. Basic research expenditures by performer, 1960-76

[Dollars in millions]

Year	Total	Federal Government laboratories	Industry	Universities and colleges	FFRDC's[1]	Other nonprofit institutions
			Current dollars			
1960	$1,183	$160	$376	$433	$97	$117
1961	1,378	206	395	536	115	126
1962	1,695	251	488	659	136	161
1963	1,974	299	522	814	159	180
1964	2,301	364	549	1,003	191	194
1965	2,572	424	592	1,138	208	210
1966	2,825	445	624	1,303	227	226
1967	3,029	472	629	1,457	250	221
1968	3,286	502	642	1,649	276	217
1969	3,378	565	618	1,707	275	213
1970	3,521	646	602	1,796	269	208
1971	3,515	535	581	1,914	260	225
1972	3,702	607	579	2,021	250	245
1973	3,816	585	621	2,058	297	255
1974	4,072	661	683	2,154	300	274
1975 (est.)	4,446	736	725	2,397	308	280
1976 (est.)	4,750	750	775	2,600	335	290
			Constant 1972 dollars[2]			
1960	$1,723	$233	$548	$631	$141	$170
1961	1,989	297	570	774	166	182
1962	2,403	356	692	934	193	228
1963	2,757	418	729	1,137	222	251
1964	3,165	501	755	1,379	263	267
1965	3,461	571	797	1,531	280	283
1966	3,680	580	813	1,697	296	294
1967	3,833	597	796	1,844	316	280
1968	3,980	608	778	1,997	334	263
1969	3,895	652	713	1,968	317	246
1970	3,854	707	659	1,966	294	228
1971	3,661	557	605	1,993	271	234
1972	3,702	607	579	2,021	250	245
1973	3,607	553	587	1,945	281	241
1974	3,498	568	587	1,850	258	235
1975 (est.)	3,494	578	570	1,884	242	220
1976 (est.)	3,551	561	579	1,944	250	217

[1] Federally Funded Research and Development Centers administered by universities.
[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), pp. 22-23.

See Figure 3-2 in text.

Table 3-3. Basic research expenditures by source[1], 1960-76

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges[2]	Other nonprofit institutions
			Current dollars		
1960	$1,183	$693	$331	$72	$87
1961	1,378	841	350	85	102
1962	1,695	1,091	382	102	120
1963	1,974	1,310	414	121	129
1964	2,301	1,595	424	144	138
1965	2,572	1,817	448	164	143
1966	2,825	1,986	496	196	147
1967	3,029	2,173	477	223	156
1968	3,286	2,327	518	276	165
1969	3,378	2,386	519	298	175
1970	3,521	2,469	509	350	193
1971	3,515	2,379	527	400	209
1972	3,702	2,525	528	428	221
1973	3,816	2,607	573	418	218
1974	4,072	2,788	615	430	239
1975 (est.)	4,446	3,029	670	476	271
1976 (est.)	4,750	3,210	715	525	300
			Constant 1972 dollars[3]		
1960	$1,723	$1,009	$482	$105	$127
1961	1,989	1,214	505	123	147
1962	2,403	1,546	541	145	170
1963	2,757	1,830	578	169	180
1964	3,165	2,194	583	198	190
1965	3,461	2,445	603	221	192
1966	3,680	2,587	646	255	192
1967	3,833	2,750	604	282	197
1968	3,980	2,818	627	334	200
1969	3,895	2,751	598	344	202
1970	3,854	2,702	557	383	211
1971	3,661	2,478	549	417	218
1972	3,702	2,525	528	428	221
1973	3,607	2,464	542	395	206
1974	3,498	2,395	528	369	205
1975 (est.)	3,494	2,380	527	374	213
1976 (est.)	3,545	2,396	534	392	224

[1] Over 50 percent of the total basic research expenditures are accounted for by universities and colleges. Because data on individual non-Federal sources of basic research expenditures are not collected by survey but are estimated by NSF, the expenditures in the last three columns of this table are only approximations.
[2] Includes State and local government sources.
[3] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), p. 29.

See Figure 3-3 in text.

Table 3-4. Federal obligations for basic research as a percent of each agency's R&D obligations by agency, 1960-76

Year	All agencies[1]	USDA	DOD	HEW	ERDA[2]	NASA[1]	NSF	All other agencies
	Basic research as a percent of all R&D obligations							
1960	NA	27	3	32	14	NA	91	19
1961	NA	29	3	32	20	NA	92	19
1962	NA	32	3	33	19	NA	91	20
1963	9	33	3	36	20	7	92	20
1964	NA	36	3	35	19	NA	91	22
1965	NA	40	4	35	21	NA	91	22
1966	NA	40	4	32	23	NA	91	18
1967	10	40	4	32	24	7	91	15
1968	11	39	3	32	21	7	89	17
1969	11	41	4	29	20	10	91	15
1970	11	41	3	32	21	9	85	12
1971	11	39	3	27	21	10	81	9
1972	12	39	3	26	21	11	81	12
1973	12	39	3	25	20	11	82	10
1974	12	38	3	25	16	10	75	10
1975	11	37	3	25	12	8	82	13
1976 (est.)	11	37	3	26	10	7	85	11
	Federal obligations for basic research (Current dollars in millions)							
1960	NA	$34	$168	$103	$104	NA	$68	$35
1961	NA	41	173	137	167	NA	77	39
1962	NA	50	204	190	192	NA	104	50
1963	$1,152	56	231	236	219	$210	141	59
1964	NA	68	241	274	238	NA	155	66
1965	NA	90	263	303	258	NA	171	77
1966	NA	94	262	326	281	NA	223	95
1967	1,728	100	284	372	302	328	239	103
1968	1,721	100	263	397	282	321	252	106
1969	1,779	107	276	371	285	380	248	112
1970	1,762	116	247	388	287	358	245	122
1971	1,779	118	262	397	277	327	273	125
1972	1,974	137	270	461	268	332	368	139
1973	2,001	143	258	458	275	350	392	125
1974	2,039	146	244	561	232	306	415	134
1975	2,146	154	236	592	247	242	486	189
1976 (est.)	2,345	177	255	670	274	244	530	195

(Continued)

Table 3-4. (Continued)

Year	All agencies[1]	USDA	DOD	HEW	ERDA[2]	NASA[1]	NSF	All other agencies
	Federal obligations for all R&D (Current dollars in millions)							
1960	$7,552	$126	$5,712	$320	$762	$369	$75	$189
1961	9,059	143	6,574	429	850	777	84	202
1962	10,290	157	6,723	577	1,029	1,439	114	251
1963	12,495	168	7,286	656	1,078	2,857	154	295
1964	14,225	189	7,262	777	1,236	4,287	170	305
1965	14,614	225	6,797	869	1,241	4,952	187	344
1966	15,320	235	7,024	1,014	1,212	5,050	244	541
1967	16,529	253	8,049	1,147	1,257	4,867	262	694
1968	15,921	254	7,709	1,252	1,369	4,429	284	625
1969	15,641	260	7,696	1,297	1,406	3,963	274	744
1970	15,340	281	7,360	1,221	1,346	3,800	289	1,043
1971	15,564	305	7,509	1,476	1,303	3,258	337	1,377
1972	16,512	350	8,318	1,751	1,298	3,157	455	1,183
1973	16,821	367	8,404	1,838	1,363	3,061	480	1,309
1974	17,438	379	8,420	2,290	1,489	3,002	556	1,302
1975	19,044	420	9,012	2,375	2,072	3,064	595	1,505
1976 (est.)	21,625	478	9,905	2,603	2,804	3,448	623	1,764

[1] Data for NASA for selected years are not available because of recent adjustments in what is considered basic research.
[2] Included only the Atomic Energy Commission prior to 1974.

NA = Not available.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977,* Vol. XXV, Detailed Statistical Tables, Appendixes C and D, (NSF 76-315), and earlier volumes.

See Figure 3-5 in text.

Table 3-5. Federal obligations for basic research by agency, 1960-76

[Dollars in millions]

Year	All agencies[1]	USDA	DOD	HEW	ERDA[2]	NASA[1]	NSF	All other agencies
	Current dollars							
1960	NA	$34	$168	$103	$104	NA	$68	$35
1961	NA	41	173	137	167	NA	77	39
1962	NA	50	204	190	192	NA	104	50
1963	$1,152	56	231	236	219	$210	141	59
1964	NA	68	241	274	238	NA	155	66
1965	NA	90	263	303	258	NA	171	77
1966	NA	94	262	326	281	NA	223	95
1967	1,728	100	284	372	302	328	239	103
1968	1,721	100	263	397	282	321	252	106
1969	1,779	107	276	371	285	380	248	112
1970	1,762	116	247	388	287	358	245	122
1971	1,779	118	262	397	277	327	273	125
1972	1,974	137	270	461	268	332	368	139
1973	2,001	143	258	458	275	350	392	125
1974	2,039	146	244	561	232	306	415	134
1975	2,146	154	236	592	247	242	486	189
1976 (est.)	2,345	177	255	670	274	244	530	195
	Constant 1972 dollars[3]							
1960	NA	$50	$245	$150	$151	NA	$99	$51
1961	NA	59	250	198	241	NA	111	56
1962	NA	71	289	269	272	NA	147	71
1963	$1,609	78	323	330	306	$293	197	82
1964	NA	94	331	377	327	NA	213	91
1965	NA	121	354	408	347	NA	230	104
1966	NA	122	341	425	366	NA	291	124
1967	2,187	127	359	471	382	415	302	130
1968	2,084	121	319	481	342	389	305	128
1969	2,051	123	318	428	329	438	286	129
1970	1,929	127	270	425	314	392	268	134
1971	1,853	123	273	413	288	341	284	130
1972	1,974	137	270	461	268	332	368	138
1973	1,891	135	244	433	260	331	371	118
1974	1,752	125	210	482	199	263	356	115
1975	1,686	121	185	465	194	190	382	149
1976 (est.)	1,753	132	191	501	205	182	396	146

[1] Data for NASA for selected years are not available. Although changes were made in what NASA considers basic research, obligations for all prior years have not yet been adjusted to reflect the change in reporting.
[2] Included only the Atomic Energy Commission prior to 1974.
[3] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities. Fiscal Years 1975, 1976 and 1977*, Vol. XXV (NSF 76-315), p. 147 and earlier volumes.

See Figure 3-6 in text.

Table 3-6. Federal obligations for basic research by field of science, 1963-76

[Dollars in millions]

Field of science	1963	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976 (est.)
	Current dollars										
All fields	$1,152	$1,728	$1,721	$1,779	$1,762	$1,779	$1,974	$2,001	$2,039	$2,146	$2,345
Life sciences	372	573	579	539	554	570	668	665	737	776	877
Biological	200	346	375	403	407	425	515	551	566	612	689
Clinical medical[1]	172	227	205	136	143	101	128	98	138	141	162
Other life sciences	—	—	([2])	([2])	4	45	25	16	33	23	26
Environmental sciences	164	209	199	235	256	280	291	299	320	331	357
Physical sciences	404	605	599	662	589	582	625	618	604	616	660
Chemistry	84	123	119	131	135	126	146	151	148	158	177
Physics	228	348	352	350	320	328	345	338	319	319	348
Astronomy	74	107	110	174	129	122	125	119	132	131	124
Other physical sciences	20	27	18	7	5	7	8	10	6	8	11
Psychology	35	60	55	53	56	48	54	51	49	48	51
Mathematics	40	65	67	56	58	51	63	57	49	59	62
Engineering	110	156	156	151	180	169	185	204	188	228	238
Social sciences	25	57	61	71	64	70	80	78	73	73	87
Other sciences	2	4	4	11	4	9	9	28	16	15	13
	Constant 1972 dollars[3]										
All fields	$1,609	$2,187	$2,084	$2,051	$1,929	$1,853	$1,974	$1,891	$1,752	$1,686	$1,753
Life sciences	520	725	701	622	606	594	668	629	633	610	656
Biological	279	438	454	465	445	443	515	521	486	481	515
Clinical medical[1]	240	287	248	157	157	105	128	93	119	111	121
Other life sciences	—	—	([2])	([2])	4	47	25	15	28	18	19
Environmental sciences	229	264	241	271	280	292	291	283	275	260	267
Physical sciences	564	766	725	763	645	606	625	584	519	484	493
Chemistry	117	156	144	151	148	131	146	143	127	124	132
Physics	318	440	426	404	350	342	345	319	274	251	260
Astronomy	103	135	133	201	141	127	125	112	113	103	93
Other physical sciences	28	34	22	8	5	7	8	9	5	6	8
Psychology	49	76	67	61	61	50	54	48	42	38	38
Mathematics	56	82	81	65	63	53	63	54	42	46	46
Engineering	154	197	189	174	197	176	185	193	161	179	178
Social sciences	35	72	74	82	70	73	80	74	63	57	65
Other sciences	3	5	5	13	4	9	9	26	14	12	10

[1] Includes "other medical sciences".
[2] Less than .5 million.
[3] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976, and 1977,* Vol. XXV, Detailed Statistical Tables, Appendices C and D (NSF 76-315), pp. 46, 149, earlier volumes, and unpublished data.

See Figure 3-7 in text.

Table 3-7. Fields and subfields of Federal obligations for basic research shown in Figure 3-6 and Appendix Table 3-6

Field of science	Illustrative subfields
Life sciences	Biological sciences: those which, apart from clinical medical and other medical sciences defined below, deal with the origin, development, structure, function, and interaction of living things.
	Clinical medical sciences: those concerned with the study of pathogenesis, diagnosis, or therapy of a particular disease or abnormal condition in living human subjects under controlled conditions.
	Other medical sciences: those concerned with the study of the causes, effects, prevention, or control of abnormal conditions in man or in his environment as they relate to health, except for the clinical aspects defined above.
	Other life sciences: multidisciplinary projects within the broad field and single discipline projects for which a separate field has not been assigned.
Environmental sciences	Atmospheric sciences: aeronomy, solar, weather modification, extraterrestrial atmospheres, and meteorology.
	Geological sciences: engineering geophysics, general geology, geodesy and gravity, geomagnetism, hydrology, inorganic geochemistry, isotopic geochemistry, organic geochemistry, laboratory geophysics, paleomagnetism, paleontology, physical geography and cartography, seismology and soil sciences.
	Oceanography: chemical oceanography, geological oceanography, physical oceanography, and marine geophysics.
	Other environmental sciences: multidisciplinary projects within the broad field and single discipline projects for which a separate field has not been assigned.
Mathematics	Algebra, analysis, applied mathematics, computer science, foundations and logic, geometry, numerical analysis, statistics, and topology.
Engineering	Aeronautical: aerodynamics.
	Astronautical: aerospace, and space technology.
	Chemical: petroleum, petroleum refining, and process.
	Civil: architectural, hydraulic, hydrologic, marine, sanitary and environmental, structural, and transportation.
	Electrical: communication, electronic, and power.
	Mechanical: engineering mechanics.
	Metallurgy and materials: ceramic, mining, textile, and welding.
	Other engineering: multidisciplinary projects within the broad field and single discipline projects for which a separate field has not been assigned, such as agricultural, industrial and management, nuclear, ocean engineering, and systems.

(Continued)

Table 3-7. (Continued)

Social sciences	Anthropology: archaeology, cultural and personality, social and ethnology, and applied anthropology.
	Economics: econometrics and economic statistics, history of economic thought, international economics, industrial, labor and agricultural economics, macroeconomics, microeconomics, public finance and fiscal policy, theory, and economic systems and development.
	History: cultural, political, social, and history and philosophy of science.
	Linguistics: anthropological-archaeological, computational, psycholinguistics, and sociolinguistics.
	Political science: area or regional studies, comparative government, history of political ideas, international relations and law, national political and legal systems, political theory, and public administration.
	Sociology: comparative and historical, complex organizations, culture and social structure, demography, group interactions, social problems and social welfare, and sociological theory.
	Other social sciences: multidisciplinary projects within the broad field and single discipline projects for which a separate field has not been assigned, such as research in law and education not elsewhere classified, and socioeconomic geography.
Psychology	Biological aspects: experimental psychology, animal behavior, clinical psychology, comparative psychology, and ethology.
	Social aspects: social psychology, educational, personnel, vocational psychology and testing, industrial and engineering psychology, and development and personality.
	Other psychological sciences: multidisciplinary projects within the broad field and single discipline projects for which a separate field has not been assigned.
Physical sciences	Astronomy: laboratory astrophysics, optical astronomy, radio astronomy, theoretical astrophysics, X-ray, Gamma-ray, and neutrino astronomy.
	Chemistry: inorganic, organo-metallic, organic, and physical.
	Physics: acoustics, atomic and molecular, condensed matter, elementary particles, nuclear structure, optics, and plasma..
	Other physical sciences: multidisciplinary projects within the broad field and single discipline projects for which a separate field has not been assigned.
Other sciences	Multidisciplinary and interdisciplinary projects that cannot be classified within one of the above broad fields of science.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977,* Vol. XXV (NSF 76-315).

Table 3-8. Basic research expenditures in universities and colleges by source[1], 1960-76

[Dollars in millions]

Year	Total	Federal Govern-ment	Industry	All other sources
	Current dollars			
1960	$433	$299	$24	$110
1961	536	382	25	129
1962	659	481	25	153
1963	814	610	25	179
1964	1,003	767	25	211
1965	1,138	879	26	233
1966	1,303	1,009	27	267
1967	1,457	1,124	31	302
1968	1,649	1,251	36	362
1969	1,707	1,275	39	393
1970	1,796	1,296	40	460
1971	1,914	1,349	46	519
1972	2,021	1,416	51	554
1973	2,058	1,459	58	541
1974	2,154	1,524	61	569
1975 (est.)	2,397	1,690	70	637
1976 (est.)	2,600	1,825	75	700
	Constant 1972 dollars[2]			
1960	$631	$435	$35	$160
1961	774	551	36	186
1962	934	682	35	217
1963	1,137	852	35	250
1964	1,379	1,055	34	290
1965	1,531	1,183	35	314
1966	1,697	1,314	35	348
1967	1,844	1,422	39	382
1968	1,997	1,515	44	438
1969	1,968	1,470	45	453
1970	1,966	1,419	44	504
1971	1,993	1,405	48	541
1972	2,021	1,416	51	554
1973	1,945	1,379	55	511
1974	1,850	1,309	52	489
1975 (est.)	1,884	1,328	55	501
1976 (est.)	1,944	1,364	56	523

[1] Over 50 percent of the total basic research expenditures are accounted for by universities and colleges. Because data on individual non-Federal sources of basic research expenditures are not collected by survey, but are estimated by the National Science Foundation, the allocation of expenditures among the last two columns may be only rough approximations.

[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), pp. 22-23.

See Figure 3-8 in text.

Table 3-9. Federal obligations for basic research in universities and colleges by selected supporting agencies and by field, 1973-76

[Dollars in millions]

Field of science[1]		Five-agency[2] total	Department of Agriculture	Department of Defense	Department of Health, Education, and Welfare	Energy Research and Development Admin.[3]	National Science Foundation	NASA
		Current dollars						
All fields	1973	$847.2	$37.2	$105.0	$317.9	$59.9	$327.2	$41.8
	1974	887.4	38.1	97.4	388.4	56.5	306.9	54.3
	1975	967.2	43.3	95.3	392.3	57.5	378.7	64.5
	1976(est.)	1,070.7	49.1	107.1	445.0	61.7	407.7	52.9
Life sciences	1973	366.3	26.2	8.3	263.5	11.1	57.2	NA
	1974	430.7	26.6	7.2	326.6	5.6	64.7	NA
	1975	451.5	30.3	9.8	332.1	—	79.3	3.7
	1976(est.)	506.8	35.0	9.9	377.0	—	84.9	3.9
Physical sciences	1973	177.3	1.9	19.9	18.0	43.0	94.5	NA
	1974	176.2	1.9	18.1	22.4	45.7	88.1	NA
	1975	201.6	2.0	18.7	26.2	48.6	106.1	33.2
	1976(est.)	220.6	2.4	21.7	29.9	51.8	114.8	27.7
Astronomy	1973	9.4	—	1.6	—	—	7.8	NA
	1974	9.0	—	.2	—	—	8.8	NA
	1975	8.8	—	.2	—	—	8.6	17.9
	1976(est.)	9.5	—	.3	—	—	9.2	17.1
Chemistry	1973	62.7	1.9	4.4	18.0	8.3	30.1	NA
	1974	64.5	1.9	4.7	22.4	5.6	29.9	NA
	1975	79.5	1.9	5.1	26.1	7.6	38.8	3.1
	1976(est.)	90.3	2.3	6.8	29.8	8.5	43.0	1.9
Physics	1973	99.7	(5)	13.3	(5)	34.7	51.7	NA
	1974	101.6	(5)	12.7	(5)	39.4	49.5	NA
	1975	112.1	.1	12.9	(5)	40.4	58.7	9.7
	1976(est.)	119.0	(5)	13.6	(5)	42.6	62.7	6.8
Other physical sciences	1973	5.5	—	.6	—	—	4.9	NA
	1974	1.0	—	.4	—	.7	—	NA
	1975	1.1	—	.4	—	.6	—	2.5
	1976(est.)	1.8	—	1.0	—	.7	—	1.9
Environmental sciences	1973	80.5	.4	28.9	(5)	—	51.2	NA
	1974	89.2	.7	20.6	—	.4	67.5	NA
	1975	102.6	.8	21.7	—	.5	79.6	16.5
	1976(est.)	113.2	.8	23.7	—	.6	88.1	12.8
Engineering	1973	75.5	1.2	26.4	3.3	3.5	41.1	NA
	1974	76.6	1.4	31.8	3.5	3.7	36.2	NA
	1975	94.4	1.8	27.6	3.8	6.8	54.4	8.4
	1976(est.)	99.1	1.5	31.6	4.3	7.5	54.0	6.9
Social sciences	1973	45.7	7.5	.1	16.2	—	21.9	NA
	1974	41.8	7.4	.2	15.1	—	19.2	NA
	1975	40.1	8.4	.3	8.5	—	23.1	.1
	1976(est.)	46.0	9.4	.1	9.8	—	26.8	.1
Psychology	1973	29.0	—	5.3	14.3	—	9.4	NA
	1974	29.6	—	7.1	17.2	—	5.3	NA
	1975	29.3	—	4.4	17.0	—	7.9	.8
	1976(est.)	34.0	—	5.8	19.6	—	8.6	1.1
Mathematics	1973	40.9	(5)	16.2	1.1	2.4	21.2	NA
	1974	36.3	.1	12.5	2.0	1.1	20.5	NA
	1975	41.6	(5)	12.8	2.3	1.6	24.9	.5
	1976(est.)	44.9	(5)	14.0	2.6	1.8	26.5	.3
Other sciences[4]	1973	32.1	—	—	1.4	—	30.7	NA
	1974	7.1	—	—	1.6	—	5.4	NA
	1975	6.2	—	.1	2.5	—	3.6	1.3
	1976(est.)	6.1	—	.3	1.9	—	3.9	.1
		Constant dollars						
All fields	1973	$800.8	$35.2	$99.2	$300.5	$56.6	$309.3	$39.5
	1974	762.3	32.7	83.7	333.6	48.5	263.6	NA
	1975	760.1	34.0	74.9	308.3	45.2	297.6	50.7
	1976(est.)	800.5	36.7	80.1	332.7	46.1	304.8	39.6
Life sciences	1973	346.2	24.8	7.8	249.1	10.5	54.1	NA
	1974	370.0	22.9	6.2	280.6	4.8	55.6	NA
	1975	354.8	23.8	7.7	261.0	—	62.3	2.9
	1976(est.)	378.9	26.2	7.4	281.9	—	63.5	2.9

(Continued)

Table 3-9. (Continued)

Field of science[1]		Five-agency[2] total	Department of Agriculture	Department of Defense	Department of Health, Education, and Welfare	Energy Research and Development Admin.[3]	National Science Foundation	NASA
		Constant dollars						
Physical sciences	1973	167.6	1.8	18.8	17.0	40.6	89.3	NA
	1974	151.4	1.6	15.5	19.2	39.3	75.7	NA
	1975	158.4	1.6	14.7	20.6	38.2	83.4	26.1
	1976(est.) .	164.9	1.8	16.2	22.4	38.7	85.8	20.7
Astronomy	1973	8.9	—	1.5	—	—	7.4	NA
	1974	7.7	—	.2	—	—	7.6	NA
	1975	6.9	—	.2	—	—	6.8	14.1
	1976(est.) .	7.1	—	.2	—	—	6.9	12.8
Chemistry	1973	59.3	1.8	4.2	17.0	7.8	28.4	NA
	1974	55.4	1.6	4.0	19.2	4.8	25.7	NA
	1975	62.5	1.5	4.0	20.5	6.0	30.5	2.4
	1976(est.) .	67.5	1.7	5.1	22.3	6.4	32.1	1.4
Physics	1973	94.2	([5])	12.6	([5])	32.8	48.9	NA
	1974	87.3	([5])	10.9	([5])	33.8	42.5	NA
	1975	88.1	([5])	10.1	([5])	31.7	46.1	7.6
	1976(est.) .	89.0	([5])	10.2	([5])	31.9	46.9	5.1
Other physical sciences	1973	5.2	—	.6	—	—	4.6	NA
	1974	.9	—	.3	—	.6	—	NA
	1975	.9	—	.3	—	.5	—	2.0
	1976(est.) .	1.3	—	.7	—	.5	—	1.4
Environmental sciences	1973	76.1	.4	27.3	([5])	—	48.4	NA
	1974	76.6	.6	17.7	—	.3	58.0	NA
	1975	80.6	.6	17.1	—	.4	62.6	13.0
	1976(est.) .	84.6	.6	17.7	—	.4	65.9	9.6
Engineering	1973	71.4	1.1	25.0	3.1	3.3	38.8	NA
	1974	65.8	1.2	27.3	3.0	3.2	31.1	NA
	1975	74.2	1.4	21.7	3.0	5.3	42.8	6.6
	1976(est.) .	74.1	1.1	23.6	3.2	5.6	40.4	5.2
Social sciences	1973	43.2	7.1	.1	15.3	—	20.7	NA
	1974	35.9	6.4	.2	13.0	—	16.5	NA
	1975	31.5	6.6	.2	6.7	—	18.2	.1
	1976(est.) .	34.4	7.0	([5])	7.3	—	20.0	.1
Psychology	1973	27.4	—	5.0	13.5	—	8.9	NA
	1974	25.4	—	6.1	14.8	—	4.6	NA
	1975	23.0	—	3.5	13.4	—	6.2	.6
	1976(est.) .	25.4	—	4.3	14.7	—	6.4	.8
Mathematics	1973	38.7	([5])	15.3	1.0	2.3	20.0	NA
	1974	31.2	.1	10.7	1.7	.9	17.6	NA
	1975	32.7	([5])	10.1	1.8	1.3	19.6	.4
	1976(est.) .	33.6	([5])	10.5	1.9	1.3	19.8	.2
Other sciences[4]	1973	30.3	—	—	1.3	—	29.0	NA
	1974	6.1	—	—	1.4	—	4.6	NA
	1975	4.9	—	.1	2.0	—	2.8	1.0
	1976(est.) .	4.6	—	.2	1.4	—	2.9	.1

[1] See Appendix table 3-7 for descriptions of these fields.
[2] Excluding the National Aeronautics and Space Administration. Data on NASA obligations for basic research by field in universities and colleges are not available for 1973 and 1974.
[3] Includes only the Atomic Energy Commission prior to 1974.
[4] Including inter- and multi-disciplinary sciences.
[5] Less than $50,000.
[6] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NA = Not available.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977*, Vol. XXV (NSF 76-315), earlier volumes, and unpublished data.

See Figure 3-10 in text.

Table 3-10. Fields and subfields of R&D expenditures at colleges and universities

Field of science	Illustrative subfields
Engineering	Aeronautical, agricultural, chemical, civil, electrical, industrial, mechanical, metallurgical, mining, nuclear, petroleum, bio-and-biomedical, energy, textile, architecture
Physical sciences	Astronomy: astrophysics, optical and radio, X-ray, gamma-ray, neutrino
	Chemistry: inorganic, organo-metallic, organic, physical, analytical, pharmaceutical, polymer science (excludes biochemistry)
	Physics: acoustics, atomic and molecular, condensed matter, elementary particles, nuclear structure, optics, plasma
	Other physical sciences: multidisciplinary projects within physical sciences, and physical sciences disciplines not described above
Environmental sciences	Atmospheric sciences: aeronomy, solar weather modification, meteorology, extraterrestrial atmospheres
	Geological sciences: engineering geophysics, geology, geodesy, geomagnetism, hydrology, geochemistry, paleomagnetism, paleontology, physical geography, cartography, seismology, soil sciences
	Oceanography: chemical, geological, physical, marine geophysics, marine biology, biological oceanography
Mathematical sciences	Mathematics: algebra, analysis, applied mathematics, foundations and logic, geometry, numerical analysis, statistics, topology
	Computer sciences: design, development, and application of computer capabilities to data storage and manipulation, information science
Life sciences	Biological sciences: anatomy, biochemistry, biophysics, biogeography, ecology, embryology, entomology, genetics, immunology, microbiology, nutrition, parasitology, pathology, pharmacology, physical anthropology, physiology, botany, zoology
	Agricultural:[1] agricultural chemistry, agronomy, animal science, conservation, dairy science, plant science, range science, wildlife
	Clinical medical: anesthesiology, cardiology, endocrinology, gastroenterology, hematology, neurology, obstetrics, ophthamology, preventive medicine and community health, psychiatry, radiology, surgery, veterinary medicine, dentistry, pharmacy
	Other life sciences: multidisciplinary projects within life sciences
Psychology	Animal behavior, clinical, educational, experimental, human development and personality, social
Social sciences	Economics: econometrics, international, industrial, labor, agricultural, public finance and fiscal policy
	Political science: regional studies, comparative government, international relations, legal systems, political theory, public administration
	Sociology: comparative and historical, complex organizations, culture and social structure, demography, group interactions, social problems and welfare, theory
	Other social sciences: history of science, cultural anthropology, linguistics, socio-economic geography, research in education
Other sciences	Multidisciplinary and interdisciplinary research not classifiable under a single primary field

[1] Included with biology prior to 1974.

SOURCE: National Science Foundation, *Expenditures for Scientific Activities at Universities and Colleges, Fiscal Year 1975* (NSF 77-307), p. 41.

See Figures 3-10 and 3-12 in text.

Table 3-11. Concentration of R&D expenditures at the 100 universities and colleges with the greatest expenditures in selected fields, 1975

[Dollars in millions]

Rank of institutions	Life sciences		Physical sciences		Social sciences		Engineering		Environmental sciences[1]		Mathematics and computer sciences		Psychology	
	Current dollars	Cumulative percent[2]	Current dollars	Cumulative percent[2]	Current dollars	Cumulative percent[2]	Current dollars	Cumulative percent[2]	Current dollars	Cumulative percent[2]	Current dollars	Cumulative percent[2]	Current dollars	Cumulative percent[2]
First 10	$422	22	$111	32	$74	30	$122	32	$115	45	$34	40	$30	38
First 20	720	38	173	49	114	46	179	47	158	62	48	56	41	51
First 30	942	50	209	60	141	57	222	58	184	72	57	67	48	60
First 40	1,107	58	238	68	162	65	255	67	201	79	64	76	53	67
First 50	1,240	65	260	74	177	71	280	74	213	84	71	83	58	72
First 60	1,356	72	275	79	188	75	302	79	223	87	73	87	61	76
First 70	1,458	77	287	82	197	79	319	84	230	90	76	90	63	79
First 80	1,545	82	297	85	205	82	332	87	235	92	77	91	65	82
First 90	1,618	85	305	87	212	85	343	90	239	94	79	92	67	84
First 100	1,679	89	312	89	218	87	353	93	243	95	80	94	68	85

[1] Includes atmospheric sciences, geological sciences and oceanography.
[2] Based on the ranking of total R&D expenditures in each field separately.

SOURCE: National Science Foundation, *Expenditures for Scientific Activities at Universities and Colleges, Fiscal Year 1975*, Detailed Statistical Tables, (NSF 76-316), derived from pp. 32-33 and 40-61 and unpublished data.

See Figure 3-12 in text and Appendix Table 3-10.

Table 3-12. Scientists and engineers[1] and basic research expenditures at 100 selected colleges and universities,[2] by source of funding, 1973 to 1975

Source	1973	1974	1975
	Current dollars (in thousands)		
Total	$1,778,895	$1,852,292	$2,082,989
Federal	1,264,467	1,320,574	1,477,425
Non-Federal	514,428	531,718	605,564
	Constant 1972 dollars[3] (in thousands)		
Total	$1,681,375	$1,591,179	$1,636,927
Federal	1,195,148	1,134,416	1,161,041
Non-Federal	486,227	456,763	475,885
	FTE scientists and engineers		
Scientists and engineers	106,701	108,268	110,001

[1] Full-time-equivalent basis, as of January.
[2] Includes only those which were among the first 100 each year in expenditures for basic research.
[3] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, unpublished data.

See Figure 3-13 in text.

Table 3-13. Basic research expenditures at Federally Funded Research and Development Centers administered by universities by source, 1964-75

[Dollars in millions]

Year	All sources: All R&D	All sources: Basic research	Federal sources: All R&D	Federal sources: Basic research	Non-Federal: All R&D	Non-Federal: Basic research
	Current dollars					
1964	$629.2	$191.0	$629.2	$191.0	(1)	(1)
1966	629.5	226.5	629.4	226.5	$0.1	(1)
1968	718.9	275.6	715.3	273.4	3.6	$2.2
1970	736.8	268.7	734.1	267.1	2.7	1.6
1972	763.6	250.2	758.3	248.0	5.3	2.2
1973	816.9	296.5	812.9	294.5	4.1	2.0
1974	865.1	299.8	861.7	298.0	3.4	1.8
1975(est.)	986.7	307.5	982.7	306.5	4.0	1.0
	Constant 1972 dollars[2]					
1964	$865.4	$262.7	$865.4	$262.7	(1)	(1)
1966	820.1	295.1	820.0	295.1	$0.1	(1)
1968	870.7	333.8	866.3	331.1	4.4	$2.7
1970	806.5	294.1	803.5	292.4	3.0	1.8
1972	763.6	250.2	758.3	248.0	5.3	2.2
1973	772.1	280.2	768.3	278.4	3.9	1.9
1974	743.1	257.5	740.2	256.0	2.9	1.5
1975(est.)	775.4	241.7	772.3	240.9	3.1	0.8

[1] Less than $50,000.
[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), and unpublished data.

See Figure 3-14 in text.

Table 3-14. Federally Funded Research and Development Centers[1]

Name	Sponsoring agency	Organizational affiliation
	Administered by universities	
Ames Laboratory	ERDA	Iowa State University of Science and Technology
Applied Physics Laboratory	NAVY	Johns Hopkins University
Applied Research Laboratory	NAVY	Pennsylvania State University
Argonne National Laboratory	ERDA	University of Chicago and Argonne Universities Assoc.
Brookhaven National Laboratory	ERDA	Associated Universities, Inc.
Center for Naval Analyses	NAVY	University of Rochester
Cerro Tololo Inter-American Observatory	NSF	Association of Universities for Research in Astronomy, Inc.
Fermi National Accelerator Laboratory (Fermilab)	ERDA	Universities Research Association, Inc.
Jet Propulsion Laboratory	NASA	California Institute of Technology
Kitt Peak National Observatory	NSF	Association of Universities for Research in Astronomy, Inc.
E.O. Lawrence Berkeley Laboratory	ERDA	University of California
E.O. Lawrence Livermore Laboratory	ERDA	University of California
Lincoln Laboratory	AIR FORCE	Massachusetts Institute of Technology
Los Alamos Scientific Laboratory	ERDA	University of California
National Astronomy and Ionsophere Center	NSF	Cornell University
National Center for Atmospheric Research	NSF	University Corporation for Atmospheric Research
National Radio Astronomy Observatory	NSF	Associated Universities, Inc.
Oak Ridge Associated Universities	ERDA	Oak Ridge Associated Universities
Plasma Physics Laboratory	ERDA	Princeton University
Space Radiation Effects Laboratory	NASA	College of William and Mary
Stanford Linear Accelerator Center	ERDA	Stanford University
	Administered by industrial firms	
Bettis Atomic Power Laboratory	ERDA	Westinghouse Electric Corporation
Frederick Cancer Research Center	HEW	Litton Bionetics, Inc., Litton Industries
Hanford Engineering Development Laboratory	ERDA	Westinghouse-Hanford Corporation
Holifield National Laboratory[2]	ERDA	Union Carbide Corporation
Idaho National Engineering Laboratory[3]	ERDA	Aerojet Nuclear Corporation
Knolls Atomic Power Laboratory	ERDA	General Electric Company
Liquid Metal Engineering Center	ERDA	Rockwell International Corporation
Mound Laboratory	ERDA	Monsanto Research Corporation
Sandia Laboratory	ERDA	Western Electric Co., Inc.—Sandia Corp.
Savannah River Laboratory	ERDA	E.I. duPont de Nemours & Co., Inc.
	Administered by other nonprofit institutions	
Aerospace Corporation	AIR FORCE	Aerospace Corporation
Analytic Services, Inc. (ANSER)	AIR FORCE	Analytic Services, Inc.
Institute for Defense Analysis	DOD	Institute for Defense Analysis
MITRE Corporation	AIR FORCE	MITRE Corporation
Pacific Northwest Laboratory	ERDA	Battelle Memorial Institute
RAND Corporation	AIR FORCE	RAND Corporation

[1] This listing includes those Federally Funded Research and Development Centers which were in existance in 1976.
[2] Formerly Oak Ridge National Laboratory (Union Carbide Corporation).
[3] Formerly National Reactor Testing Station (Aerojet Nuclear Corporation).

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976, and 1977*, Vol. XXV (NSF 77-301).

Table 3-15. Federal obligations for intramural basic research by selected agencies, 1960-76

[Dollars in millions]

Year	All agencies[1]	Dept. of Defense	National Aeronautics and Space Admin.[1]	Dept. of Agriculture	Dept. of Health, Education and Welfare	Dept. of the Interior	Dept. of Commerce	All other agencies
	Current dollars							
1960	NA	$53	NA	$23	$18	$19	$9	$11
1961	NA	54	NA	28	25	21	11	18
1962	NA	64	NA	32	31	23	15	22
1963	$255	73	$39	37	39	24	19	23
1964	NA	76	NA	43	45	26	21	25
1965	NA	80	NA	57	47	31	22	29
1966	NA	85	NA	62	59	34	20	29
1967	418	82	110	63	67	40	22	35
1968	410	86	88	67	70	41	24	35
1969	516	90	153	77	88	43	26	39
1970	541	96	134	85	114	40	36	36
1971	491	99	128	87	68	41	35	33
1972	538	113	133	97	77	47	33	38
1973	537	112	141	100	79	55	14	36
1974	611	104	164	103	87	63	15	75
1975	645	99	135	107	118	100	17	68
1976(est.)	692	104	134	123	132	104	16	77
	Constant 1972 dollars[2]							
1960	NA	$77	NA	$33	$26	$28	$13	$16
1961	NA	78	NA	40	36	30	16	26
1962	NA	91	NA	45	44	33	21	31
1963	$356	102	$54	52	54	34	27	32
1964	NA	105	NA	59	62	36	29	34
1965	NA	108	NA	77	63	42	30	39
1966	NA	111	NA	81	77	44	26	38
1967	529	104	139	80	85	51	28	44
1968	497	104	107	81	85	50	29	42
1969	595	104	176	89	101	50	30	45
1970	592	105	147	93	125	44	39	39
1971	511	103	133	91	71	43	36	34
1972	538	113	133	97	77	47	33	38
1973	508	106	133	95	75	52	13	34
1974	525	89	141	88	75	54	13	64
1975	507	78	106	88	93	79	13	53
1976(est.)	517	78	100	92	99	78	12	58

[1] Data for NASA for selected years are not available. Although changes were made in what NASA considers basic research, obligations for all prior years have not yet been adjusted to reflect the change in reporting.
[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NA = Not available.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976 and 1977*, Vol. XXV (NSF 76-315), earlier volumes, and unpublished data.

See Figure 3-15 in text.

Table 3-16. Basic research expenditures in industry by source, 1960-76

[Dollars in millions]

Year	Total: Current dollars	Total: Constant 1972 dollars[1]	Industry: Current dollars	Industry: Constant 1972 dollars[1]	Federal Government: Current dollars	Federal Government: Constant 1972 dollars[1]
1960	$376	$548	$297	$433	$79	$115
1961	395	570	314	453	81	117
1962	488	692	345	489	143	203
1963	522	729	375	524	147	205
1964	549	755	384	528	165	227
1965	592	797	406	546	186	250
1966	624	813	451	588	173	225
1967	629	796	427	540	202	256
1968	642	778	462	560	180	218
1969	618	713	458	528	160	185
1970	602	659	444	486	158	173
1971	581	605	456	475	125	130
1972	579	579	452	452	127	127
1973	621	587	485	458	136	129
1974	683	587	524	450	159	137
1975(est.) .	725	570	565	444	160	126
1976(est.) .	775	579	605	452	170	127

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), p. 23.

See Figure 3-16 in text.

Table 3-17. Expenditures for basic research in industry by major R&D-performing industries, 1960-74

[Dollars in millions]

Year	All industries	Aircraft and missiles	Electrical equipment and communication	Machinery	Chemicals and allied products	All other industries
	Current dollars					
1960	$376	$62	$77	$22	$115	$100
1961	395	40	79	25	124	127
1962	488	55	125	27	136	145
1963	522	59	133	25	152	153
1964	549	68	134	26	153	168
1965	592	74	148	22	173	175
1966	624	74	122	26	176	226
1967	629	73	131	26	184	215
1968	642	71	134	31	201	205
1969	618	67	134	21	206	190
1970	602	63	144	20	203	172
1971	581	54	145	20	212	150
1972	579	61	154	23	206	135
1973	621	50	176	24	222	149
1974	683	53	181	26	267	156
	Constant 1972 dollars[1]					
1960	$548	$90	$112	$32	$167	$147
1961	570	58	114	36	179	183
1962	692	78	177	38	193	206
1963	729	82	186	35	212	214
1964	755	94	184	36	210	231
1965	797	100	199	30	233	235
1966	813	96	159	34	229	294
1967	796	92	166	33	233	272
1968	778	86	162	38	243	248
1969	713	77	155	24	238	219
1970	659	69	158	22	222	188
1971	605	56	151	21	221	156
1972	579	61	154	23	206	135
1973	587	47	166	23	210	141
1974	587	46	155	22	229	134

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), p. 64, and earlier volumes.

See Figure 3-17 in text.

Table 3-18. Expenditures for basic research in industry by selected fields, 1967-74

[Dollars in millions]

Field[1]	1967	1968	1969	1970	1971	1972	1973	1974
	Current dollars							
Total	$629	$642	$618	$602	$581	$579	$621	$683
Physical sciences	308	317	324	297	281	275	273	318
Chemistry	162	191	213	196	180	181	192	230
Physics and astronomy	146	126	111	101	101	94	81	88
Mathematics	12	13	13	13	14	12	14	14
Environmental sciences	14	11	11	8	8	6	7	10
Engineering (including metallurgy)	172	181	170	170	159	182	182	169
Life sciences	69	76	74	86	94	81	100	112
Biological sciences	NA	50	58	51	57	60	75	83
Clinical medical sciences	NA	26	16	35	37	21	25	27
Other sciences	53	43	26	28	24	23	46	59
	Constant 1972 dollars[2]							
Total	$796	$778	$713	$659	$605	$579	$587	$587
Physical sciences	390	384	374	325	293	275	258	273
Chemistry	205	231	246	215	187	181	181	198
Physics and astronomy	185	153	128	111	105	94	77	76
Mathematics	15	16	15	14	15	12	13	12
Environmental sciences	18	13	13	9	8	6	7	9
Engineering (including metallurgy)	218	219	196	186	166	182	172	145
Life sciences	87	92	85	94	98	81	95	96
Biological sciences	NA	61	67	56	59	60	71	71
Clinical medical sciences	NA	31	18	38	39	21	24	23
Other sciences	67	52	30	31	25	23	43	51

[1] See Appendix Table 3-19 for descriptions of these fields.
[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: NA = not available. Life sciences total includes "other life sciences" for 1974.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), p. 65.

See Figure 3-18 in text.

Table 3-19. Fields of industrial basic research expenditures shown in Figure 3-18 and Appendix Table 3-18

Field of science	Illustrative subfields
Physical sciences	Chemistry Physics Astronomy
Mathematics	All mathematics fields
Engineering	Aeronautical, astronautical, chemical, civil, electrical and mechanical engineering, and metallurgy and materials.
Life sciences	Biological—All sciences other than clinical medical sciences, which deal with life processes, including plant and animal sciences, bacteriology, pathology, microbiology, pharmacology, etc.
	Clinical medical—All sciences concerned with the use of scientific knowledge for the identification, treatment, and cure of disease. Includes internal medicine, neurology, preventive medicine, and public health, psychiatry, dentistry, pharmacy, etc.
Other sciences	Multidisciplinary and interdisciplinary projects which cannot be classified within one of the above primary fields of science.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), developed from pp. 76, 82.

Table 3-20. Basic research expenditures in nonprofit institutions[1] by source, 1960-76

[Dollars in millions]

Year	Current dollars				Constant 1972 dollars[2]			
	Total	Federal Govern-ment	Industry	Own funds[3]	Total	Federal Govern-ment	Industry	Own funds[3]
1960	$117	$58	$10	$49	$170	$84	$15	$71
1961	126	57	11	58	182	82	16	84
1962	161	80	12	69	228	113	17	98
1963	180	95	14	71	251	133	20	99
1964	194	108	15	71	267	149	21	98
1965	210	120	16	74	283	161	22	100
1966	226	132	18	76	294	172	23	99
1967	221	125	19	77	280	158	24	97
1968	217	118	20	79	263	143	24	96
1969	213	111	22	80	246	128	25	92
1970	208	100	25	83	228	109	27	91
1971	225	110	25	90	234	115	26	94
1972	245	125	25	95	245	125	25	95
1973	255	130	30	95	241	123	28	90
1974	274	144	30	100	235	124	26	86
1975(est.) .	280	135	35	110	220	106	28	86
1976(est.) .	290	130	35	125	217	97	26	93

[1] Includes State-administered hospitals.
[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
[3] Includes State and local government funds.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), pp. 22-23.

See Figure 3-19 in text.

Table 3-21. Relative growth in scientific research articles by selected fields of science, 1960-75

Field of science	Percent growth after 1960										
	1962	1964	1966	1968	1969	1970	1971	1972	1973	1974	1975
Astronomy ..	17	44	66	90	107	107	124	144	144	180	194
Atmospheric sciences ...	56	79	117	198	181	223	231	263	240	313	379
Biology	22	47	77	102	113	114	119	130	142	135	141
Chemistry ...	28	47	56	82	75	77	67	94	87	73	69
Economics ..	-3	-7	5	15	33	26	26	25	25	31	25
Engineering .	7	39	56	72	74	90	94	92	79	94	82
Geology	7	15	24	32	43	39	55	50	69	57	68
Mathematics .	22	42	84	117	159	162	162	195	193	164	183
Oceanography	19	20	49	76	116	91	84	100	75	92	76
Physics	35	47	72	109	108	96	99	98	93	101	106
Political science	-6	3	8	31	58	53	44	50	53	38	42
Psychology ..	15	141	129	145	198	234	263	256	335	323	NA
Sociology ...	56	177	176	216	216	199	226	275	209	202	NA
All fields .	19	62	75	99	115	123	130	139	146	148	[1]154

[1] Estimated.

SOURCE: National Federation of Abstracting and Indexing Services, *Science Literature Indicators Study, 1975, 1976*. (A study commissioned specifically for this report).

See Figure 3-20 in text.

Table 3-22. Publication output for selected fields of science, percent of yearly totals by sectors, 1960-75

Field and sector	1960	1962	1964	1966	1968	1969	1970	1971	1972	1973	1974	1975
Astronomy												
Academic	71	79	80	74	76	79	84	84	82	79	79	79
Industry	5	—	3	6	4	5	3	4	5	4	3	3
Government	20	10	8	19	18	16	12	11	12	16	13	5
Nonprofit	2	4	3	1	3	—	—	—	1	1	5	12
Other	2	6	5	—	—	—	2	1	—	—	([1])	1
Atmospheric sciences												
Academic	56	53	53	50	53	52	60	57	56	58	58	57
Industry	6	9	13	19	12	12	9	7	11	10	8	8
Government	31	36	32	26	32	33	29	33	31	29	29	21
Nonprofit	8	2	2	4	1	1	1	2	3	3	5	15
Other	—	—	—	2	1	2	1	2	—	1	1	—
Biology												
Academic	70	78	73	73	79	75	80	78	79	81	73	81
Industry	5	3	3	5	4	3	3	3	3	2	1	([1])
Government	16	14	14	13	10	14	12	12	11	10	14	12
Nonprofit	7	4	8	7	6	6	5	6	6	7	12	7
Other	2	1	2	2	1	1	1	1	1	([1])	—	—
Chemistry												
Academic	59	61	62	60	70	68	68	69	77	75	77	77
Industry	25	30	29	26	21	24	23	22	17	18	14	19
Government	11	8	5	10	7	7	8	6	4	5	7	4
Nonprofit	3	1	2	4	1	1	1	2	1	([1])	2	—
Other	2	([1])	1	1	1	1	1	1	1	1	—	—
Economics												
Academic	72	75	70	83	87	82	92	81	88	78	95	82
Industry	7	8	14	6	6	—	1	6	3	5	1	5
Government	11	10	11	8	4	16	4	8	3	9	1	9
Nonprofit	3	—	—	—	—	—	—	—	—	1	3	2
Other	7	7	5	3	3	2	3	5	7	7	—	1
Engineering												
Academic	25	25	27	29	33	33	34	37	36	39	34	37
Industry	58	60	55	50	49	48	48	48	49	44	43	47
Government	12	14	15	17	15	16	14	13	13	14	18	13
Nonprofit	2	([1])	2	2	1	2	2	2	1	2	2	2
Other	3	2	1	2	1	1	1	1	1	1	3	2
Geology												
Academic	51	48	56	58	70	58	60	66	68	67	68	72
Industry	14	23	13	20	14	22	15	10	14	10	12	11
Government	18	18	20	15	10	14	16	17	11	18	16	17
Nonprofit	3	4	5	2	3	3	9	7	6	3	4	—
Other	15	8	6	5	2	4	1	1	2	2	—	—
Mathematics												
Academic	77	70	79	77	88	90	91	93	93	92	90	94
Industry	17	18	13	18	6	6	5	5	5	5	7	4
Government	3	5	1	2	4	1	3	2	2	2	1	1
Nonprofit	—	—	1	—	—	—	—	—	([1])	—	1	—
Other	2	7	7	3	1	3	([1])	([1])	([1])	([1])	1	([1])
Oceanography												
Academic	63	67	71	55	57	56	67	67	61	64	62	70
Industry	2	4	2	5	10	9	10	12	7	7	5	3
Government	33	22	21	26	25	30	18	13	24	21	22	24
Nonprofit	2	7	7	12	8	4	4	9	5	7	11	3
Other	—	1	—	2	—	1	1	—	2	1	1	—

(Continued)

Table 3-22. (Continued)

Field and sector	1960	1962	1964	1966	1968	1969	1970	1971	1972	1973	1974	1975
Physics												
Academic	50	57	62	62	66	70	68	66	61	72	69	68
Industry	28	29	27	29	23	19	19	17	20	16	16	19
Government	17	12	8	7	10	10	12	15	18	11	13	12
Nonprofit	4	2	2	2	1	—	([1])	1	—	—	2	1
Other	1	—	([1])	—	—	1	1	—	([1])	—	—	—
Political science												
Academic	81	85	84	85	89	89	93	83	81	91	93	90
Industry	—	—	5	3	4	4	2	6	4	2	1	3
Government	6	9	5	8	2	4	4	6	7	5	3	3
Nonprofit	8	—	5	5	—	2	—	2	2	—	2	2
Other	6	6	—	—	4	2	2	4	6	2	1	2
Psychology												
Academic	58	65	64	71	78	79	70	75	74	74	73	NA
Industry	4	3	1	1	1	2	2	3	3	2	3	NA
Government	7	12	6	7	7	7	6	5	5	10	6	NA
Nonprofit	9	7	9	12	5	7	16	11	12	10	11	NA
Other	21	14	19	8	8	5	6	6	7	4	7	NA
Sociology												
Academic	63	64	66	83	82	86	86	86	83	90	90	NA
Industry	2	4	3	2	([1])	1	2	2	1	1	—	NA
Government	4	7	6	2	4	3	4	3	4	3	1	NA
Nonprofit	—	3	7	4	5	4	2	3	3	2	4	NA
Other	31	22	19	9	8	6	6	6	9	3	5	NA

[1] Less than 0.5 percent.

SOURCE: National Federation of Abstracting and Indexing Services, *Science Literature Indicators Study, 1975*. 1976. (A study commissioned specifically for this report.)

See Figure 3-21 in text.

Table 4-1. Expenditures for industrial R&D by source of funds, 1960-76

[Dollars in billions]

Year	Current dollars			Constant 1972 dollars[1]		
	Total	Industry[2]	Federal Government	Total	Industry[2]	Federal Government
1960	$10.5	$4.4	$6.1	$15.3	$6.4	$8.9
1961	10.9	4.7	6.2	15.7	6.7	9.0
1962	11.5	5.0	6.4	16.2	7.1	9.1
1963	12.6	5.4	7.3	17.6	7.5	10.2
1964	13.5	5.8	7.7	18.6	8.0	10.6
1965	14.2	6.4	7.7	19.1	8.7	10.4
1966	15.5	7.2	8.3	20.3	9.4	10.9
1967	16.4	8.0	8.4	20.7	10.1	10.6
1968	17.4	8.9	8.6	21.1	10.7	10.4
1969	18.3	9.9	8.5	21.1	11.4	9.7
1970	18.1	10.3	7.8	19.8	11.3	8.5
1971	18.3	10.6	7.7	19.1	11.1	8.0
1972	19.4	11.3	8.1	19.4	11.3	8.1
1973	20.9	12.7	8.2	19.8	12.0	7.8
1974	22.4	14.0	8.3	19.2	12.0	7.1
1975(est.)	24.3	15.1	9.2	19.1	11.9	7.2
1976(est.)	26.5	16.3	10.2	19.8	12.2	7.6

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
[2] Includes all sources other than the Federal Government.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), pp. 20-21.

See Figure 4-1 in text.

Table 4-2. Scientists and engineers[1] engaged in industrial R&D by source of funds, 1960-75

Year	Total	Industry[2]	Federal Government
1960	292,000	NA	NA
1961	312,100	NA	NA
1962	312,000	172,800	139,200
1963	327,300	169,500	157,800
1964	340,200	174,600	165,600
1965	343,600	180,400	163,200
1966	353,200	190,300	162,900
1967	367,200	205,700	161,300
1968	376,700	219,600	156,800
1969	387,100	229,500	157,700
1970	384,100	235,900	148,200
1971	366,800	237,800	129,000
1972	349,900	232,000	118,100
1973	356,600	238,400	118,200
1974	358,200	249,700	108,600
1975	357,500	249,400	108,300

[1] Full-time-equivalent basis, as of January of each year.
[2] Includes all sources other than the Federal Government.

NOTE: Detail may not add to totals because of rounding. Preliminary data are shown for 1975.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), pp. 44, 46, and earlier volumes.

See Figure 4-3 in text.

Table 4-3. Scientists and engineers engaged in industrial R&D, compared with constant dollar expenditures for industrial R&D, 1960-75

[Index: 1960 = 100]

Year	Scientists and engineers[1]	Expenditures in constant dollars[2]
1960	100.0	100.0
1961	103.3	102.6
1962	105.8	106.2
1963	110.5	115.3
1964	113.2	121.4
1965	115.3	124.7
1966	119.3	132.4
1967	123.1	135.5
1968	126.4	137.9
1969	127.7	138.0
1970	124.3	129.2
1971	118.6	124.6
1972	117.0	126.7
1973	118.3	129.1
1974	118.5	125.8
1975	119.2[3]	124.8[4]

[1] Full-time-equivalent basis, averaged for each year.
[2] GNP implicit price deflators used to convert current to constant dollars.
[3] Preliminary.
[4] Estimated.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), p. 44 and earlier volumes, and *National Patterns of R&D Resources, 1953-76* (NSF 76-310), pp. 20-21.

See Figure 4-4 in text.

Table 4-4. R&D expenditures by industry, 1960-74

Industry	1960	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
	Current dollars in millions													
Total	$10,509	$11,464	$12,630	$13,512	$14,185	$15,548	$16,385	$17,429	$18,308	$18,062	$18,311	$19,383	$20,921	$22,369
Food and kindred products	104	121	130	144	157	164	183	187	205	235	245	260	268	294
Textiles and apparel	38	28	30	32	38	51	57	58	60	58	59	61	64	68
Lumber, wood products, and furniture	10	10	11	12	11	12	12	19	15	48	48	51	55	67
Paper and allied products	56	65	69	77	94	117	128	144	188	178	187	189	194	219
Chemicals and allied products	980	1,175	1,239	1,284	1,356	1,407	1,507	1,588	1,659	1,766	1,819	1,896	2,062	2,364
Industrial chemicals	666	738	809	865	908	918	966	985	1,013	1,040	1,020	1,042	1,135	1,322
Drugs and medicines	162	195	216	234	267	308	343	393	434	464	510	547	616	703
Other chemicals	152	242	214	185	181	181	198	210	212	262	289	307	312	338
Petroleum refining and extraction	296	310	317	393	397	371	371	437	467	515	505	468	498	598
Rubber products	121	141	156	158	162	168	182	205	217	220	230	264	280	291
Stone, clay, & glass products	88	96	100	109	112	117	136	142	159	157	155	165	175	189
Primary metals	177	171	183	195	213	232	242	251	257	275	272	261	276	316
Ferrous metals and products	102	97	106	116	128	139	135	135	136	149	144	138	147	163
Nonferrous metals and products	75	74	77	79	85	93	107	115	121	126	128	122	130	153
Fabricated metal products	145	146	153	148	145	154	163	183	182	200	233	241	273	288
Machinery	949	914	958	1,015	1,065	1,217	1,326	1,477	1,536	1,649	1,773	1,960	2,191	2,493
Office, computing, and accounting machines	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	1,215	1,319	1,539
Electrical equipment and communications	2,532	2,639	2,866	2,972	3,200	3,626	3,867	4,105	4,401	4,352	4,534	4,916	5,280	5,487
Radio and TV receiving equipment	[2]	[2]	[2]	[2]	[2]	47	45	55	57	70	64	48	49	51
Electronic components	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	317	378	383
Communication equipment and communication	1,324	1,591	1,773	1,872	1,989	2,249	2,425	2,538	2,713	2,736	2,881	2,842	3,039	3,032
Other electrical equipment	1,208	1,048	1,093	1,100	1,211	1,330	1,397	1,512	1,631	1,546	1,589	1,710	1,814	2,021
Motor vehicles and motor vehicles equipment	884	999	1,090	1,182	1,230	1,344	1,354	1,491	1,558	1,582	1,756	1,983	2,437	2,423
Other transportation equipment	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	25	27	31
Aircraft and missiles	3,514	4,042	4,712	5,078	5,148	5,526	5,669	5,776	5,909	5,245	4,912	4,992	5,084	5,311
Professional and scientific instruments	329	309	284	331	403	468	542	660	734	745	744	817	911	1,008
Scientific and mechanical measuring instruments	160	101	70	74	80	87	104	112	109	118	110	124	117	121
Optical, surgical, photographic, and other instruments	169	208	214	257	323	381	438	548	625	627	633	694	794	887

(Continued)

Table 4-4. (Continued)

Industry	1960	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Other manufacturing industries	119	65	54	65	71	77	90	102	107	132	136	150	158	174
Nonmanufacturing industries	168	234	276	319	384	497	559	603	655	705	704	707	715	779
	Constant 1972 dollars in millions[3]													
Total	$15,304	$16,249	$17,642	$18,583	$19,086	$20,255	$20,735	$21,108	$21,112	$19,770	$19,070	$19,383	$19,752	$19,250
Food and kindred products	151	172	182	198	211	214	232	226	236	257	255	260	253	253
Textiles and apparel	55	40	42	44	51	66	72	70	69	63	61	61	60	58
Lumber, wood products, and furniture	15	14	15	17	15	16	15	23	17	53	50	51	52	58
Paper and allied products	82	92	96	106	126	152	162	174	217	195	195	189	183	188
Chemicals and allied products	1,427	1,665	1,731	1,766	1,825	1,833	1,907	1,923	1,913	1,933	1,894	1,896	1,949	2,031
Industrial chemicals	970	1,046	1,130	1,190	1,222	1,196	1,222	1,193	1,168	1,138	1,062	1,042	1,073	1,136
Drugs and medicines	236	276	302	322	359	401	434	476	500	508	531	547	582	604
Other chemicals	221	343	299	254	244	236	251	254	244	287	301	307	295	290
Petroleum refining and extraction	431	439	443	541	534	483	470	529	539	564	526	468	471	514
Rubber products	176	200	218	217	218	219	230	248	250	241	240	264	265	250
Stone, clay, & glass products	128	136	140	150	151	152	172	172	183	172	161	165	165	162
Primary metals	258	242	256	268	287	302	306	304	296	301	283	261	261	271
Ferrous metals and products	149	137	148	160	172	181	171	163	157	163	150	138	139	140
Nonferrous metals and products	109	105	108	109	114	121	135	139	140	138	133	122	123	131
Fabricated metal products	211	207	214	204	195	201	206	222	210	219	243	241	258	247
Machinery	1,382	1,296	1,338	1,396	1,433	1,585	1,678	1,789	1,771	1,805	1,846	1,960	2,071	2,142
Office, computing, and accounting machines	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	1,215	1,247	1,322
Electrical equipment and communication	3,687	3,741	4,003	4,087	4,306	4,724	4,894	4,972	5,075	4,764	4,722	4,916	4,991	4,714
Radio and TV receiving equipment	(2)	(2)	(2)	(2)	(2)	61	57	67	66	77	67	48	46	44
Electronic components	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	317	357	329
Communication equipment and communication	1,928	2,255	2,477	2,575	2,676	2,930	3,069	3,074	3,128	2,995	3,000	2,842	2,872	2,605
Other electrical equipment	1,759	1,485	1,527	1,513	1,629	1,733	1,768	1,831	1,881	1,692	1,655	1,710	1,715	1,736

(Continued)

Table 4-4. (Continued)

Industry	1960	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
	Constant 1972 dollars in millions[3]													
Motor vehicles and motor vehicles equipment	1,287	1,416	1,523	1,626	1,655	1,751	1,713	1,806	1,797	1,732	1,829	1,983	2,303	2,081
Other transportation equipment	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	25	26	27
Aircraft and missiles	5,117	5,729	6,582	6,984	6,927	7,199	7,174	6,995	6,814	5,741	5,116	4,992	4,805	4,562
Professional and scientific instruments	479	438	397	455	542	610	686	799	846	815	775	817	861	866
Scientific and mechanical measuring instruments	233	143	98	102	108	113	132	136	126	129	115	124	111	104
Optical, surgical, photographic, and other instruments	246	295	299	353	435	496	554	664	721	686	659	694	750	762
Other manufacturing industries	173	92	75	89	96	100	114	124	123	144	142	150	149	149
Nonmanufacturing industries	245	332	386	439	517	647	707	703	755	772	733	707	676	669

[1] Data not tabulated at this level prior to 1972.
[2] Included in the other electrical equipment group.
[3] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), p. 26, and *Research and Development in Industry, 1971* (NSF 73-305), p. 28.

See Figure 4-5 in text.

Table 4-5. Industrial R&D expenditures, percent change, 1970-74

Industry	Current dollars (in millions)		Constant 1972 dollars[1] (in millions)		Percent change	
	1970	1974	1970	1974	Current dollars	Constant dollars
Total	$18,062	$22,369	$19,770	$19,216	23.8	-2.8
Motor vehicles and other transportation equipment	1,582	2,423	1,732	2,081	53.2	20.2
Machinery	1,649	2,493	1,805	2,142	51.2	18.7
Fabricated metal products	200	288	219	247	44.0	12.8
Lumber, wood products, and furniture	48	67	53	58	39.6	9.4
Professional and scientific instruments	745	1,008	815	866	35.3	6.3
Chemicals and allied products	1,766	2,364	1,933	2,031	33.9	5.1
Rubber products	220	291	241	250	32.3	3.7
Electrical equipment and communication	4,352	5,487	4,764	4,714	26.1	-1.0
Food and kindred products	235	294	257	253	25.1	-1.6
Paper and allied products	178	219	195	188	23.0	-3.6
Stone, clay, and glass products	157	189	172	162	20.4	-5.8
Textiles and apparel	58	68	63	58	17.2	-7.9
Petroleum refining and extraction	515	598	564	514	16.1	-8.9
Primary metals	275	316	301	271	14.9	-10.0
Aircraft and missiles	5,245	5,311	5,741	4,562	1.3	-20.5

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), p. 26.

See Figure 4-6 in text.

Table 4-6. Industrial R&D expenditures, for basic research, applied research, and development, 1960-76

[Dollars in millions]

Year	Total	Basic research	Applied research	Development
	Current dollars			
1960	$10,509	$376	$2,029	$8,104
1961	10,908	395	1,977	8,536
1962	11,464	488	2,449	8,527
1963	12,630	522	2,457	9,651
1964	13,512	549	2,600	10,363
1965	14,185	592	2,658	10,935
1966	15,548	624	2,843	12,081
1967	16,385	629	2,915	12,841
1968	17,429	642	3,124	13,663
1969	18,308	618	3,287	14,403
1970	18,062	602	3,426	14,034
1971	18,311	581	3,413	14,317
1972	19,383	579	3,471	15,333
1973	20,921	621	3,739	16,561
1974	22,369	683	4,129	17,557
1975(est.)	24,250	725	4,450	19,075
1976(est.)	26,500	775	4,800	20,925
	Constant 1972 dollars[1]			
1960	$15,304	$548	$2,955	$11,801
1961	15,745	570	2,854	12,321
1962	16,249	692	3,471	12,086
1963	17,642	729	3,432	13,481
1964	18,583	755	3,576	14,253
1965	19,086	797	3,576	14,713
1966	20,255	813	3,704	15,739
1967	20,735	796	3,689	16,250
1968	21,108	778	3,783	16,547
1969	21,112	713	3,790	16,609
1970	19,770	659	3,750	15,361
1971	19,070	605	3,554	14,910
1972	19,383	579	3,471	15,333
1973	19,774	587	3,534	15,653
1974	19,216	587	3,547	15,082
1975(est.)	19,057	570	3,497	14,990
1976(est.)	19,813	579	3,589	15,645

[1] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), pp. 20-27.

See Figure 4-11 in text.

Table 4-7. Allocation of R&D expenditures in industry between research and development, by source of funds, 1965-76

Year	Development			Basic and applied research		
	Total	Federal Govern-ment	Industry[1]	Total	Federal Govern-ment	Industry[1]
	Percent of total					
1965	100.0	59.6	40.4	100.0	37.7	62.3
1966	100.0	58.9	41.1	100.0	35.0	65.0
1967	100.0	55.3	44.7	100.0	35.8	64.2
1968	100.0	53.7	46.3	100.0	32.5	67.5
1969	100.0	50.5	49.5	100.0	30.1	69.9
1970	100.0	46.8	53.2	100.0	30.0	70.0
1971	100.0	45.9	54.1	100.0	27.5	72.5
1972	100.0	45.5	54.5	100.0	26.4	73.6
1973	100.0	43.0	57.0	100.0	25.5	74.5
1974	100.0	40.4	59.6	100.0	25.6	74.4
1975(est.) .	100.0	41.1	58.9	100.0	25.3	74.7
1976(est.) .	100.0	42.0	58.0	100.0	25.5	74.5
	Dollars in millions					
1965	$10,935	$6,516	$4,419	$3,250	$1,224	$2,026
1966	12,081	7,120	4,961	3,467	1,212	2,255
1967	12,841	7,097	5,744	3,544	1,268	2,276
1968	13,663	7,337	6,326	3,766	1,223	2,543
1969	14,403	7,276	7,127	3,905	1,175	2,730
1970	14,034	6,572	7,462	4,028	1,207	2,821
1971	14,317	6,567	7,750	3,994	1,099	2,895
1972	15,333	6,979	8,354	4,050	1,068	2,982
1973	16,561	7,114	9,447	4,360	1,111	3,249
1974	17,557	7,098	10,459	4,812	1,233	3,579
1975(est.) .	19,075	7,840	11,235	5,175	1,310	3,865
1976(est.) .	20,925	8,780	12,145	5,575	1,420	4,155

[1] Includes all sources other than the Federal Government.

SOURCE: National Science Foundation, *National Patterns of R&D Resources, 1953-76* (NSF 76-310), pp. 23, 25, and 27.

See Figure 4-12 in text.

Table 4-8. Product fields for which applied research and development expenditures are reported

Ordnance, except guided missiles
Guided missiles and spacecraft
Food and kindred products
Textile mill products
Chemicals, except drugs and medicines
Industrial inorganic and organic chemicals
Plastics materials and synthetic resins, rubber, and fibers
Agricultural chemicals
Other chemicals
Drugs and medicines
Petroleum refining and extraction
Rubber and miscellaneous plastics products
Stone, clay, and glass products
Primary metals
Ferrous metals and products
Nonferrous metals and products
Fabricated metal products
Machinery
Engines and turbines
Farm machinery and equipment
Construction, mining, and materials handling machinery
Metalworking machinery and equipment
Office, computing, and accounting machines
Other machinery, except electrical
Electrical equipment, except communication
Electric transmission and distribution equipment
Electrical industrial apparatus
Other electrical equipment and supplies
Communication equipment and electronic components
Motor vehicles and other transportation equipment
Motor vehicles and equipment
Other transportation equipment
Aircraft and parts
Professional and scientific instruments

See Tables 4-13 and 4-14 in text.

Table 4-9. R&D intensity of U.S. manufacturing industries, 1961-74

Industry group	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
	Total R&D as a percent of net sales													
Group I	9.4	9.2	10.0	10.1	9.4	8.8	8.7	8.1	7.9	7.1	6.9	6.8	6.4	6.0
Group II	2.1	2.1	2.1	2.2	2.0	1.9	1.9	1.8	1.8	1.9	1.8	1.8	1.8	1.5
Group III	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.7	0.7	0.6	0.6	0.5	0.5
	Company funds for R&D as a percent of net sales													
Group I	3.2	3.2	3.4	3.4	3.5	3.4	3.6	3.5	3.7	3.5	3.5	3.4	3.4	3.3
Group II	1.7	1.6	1.6	1.7	1.6	1.6	1.5	1.5	1.6	1.7	1.6	1.6	1.6	1.4
Group III	0.4	0.5	0.4	0.5	0.5	0.4	0.6	0.4	0.4	0.5	0.4	0.5	0.4	0.3
	R&D scientists and engineers per 1,000 employees													
Group I	53.0	49.8	54.0	54.6	52.6	46.2	46.0	44.7	43.8	44.0	43.1	40.7	40.3	40.7
Group II	17.1	17.6	17.0	17.1	16.7	15.9	15.8	15.5	15.9	15.7	16.7	16.6	16.1	16.5
Group III	6.4	5.8	5.4	5.9	6.0	5.9	6.2	6.3	6.2	5.8	6.2	5.9	5.8	5.8

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), pp. 26, 31, 44, 49, 52, 54-56, and earlier volumes.

See Figure 4-17 in text.

Table 4-10. U.S. patents granted, by inventor and date of grant, 1960-76

Year	All U.S. patents	To U.S. residents	To foreign residents
1960	47,170	39,472	7,698
1961	48,368	40,154	8,214
1962	55,691	45,579	10,112
1963	45,679	37,174	8,505
1964	47,375	38,411	8,964
1965	62,857	50,332	12,525
1966	68,408	54,636	13,772
1967	65,652	51,274	14,378
1968	59,103	45,783	13,320
1969	67,560	50,398	17,162
1970	64,432	47,077	17,355
1971	78,320	55,980	22,340
1972	74,814	51,520	23,294
1973	74,148	51,509	22,639
1974	76,281	50,648	25,633
1975	72,029	46,731	25,298
1976	70,220	44,280	25,940

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *OTAF Special Report—All Technologies* (May 1977), unpublished; and U.S. Commissioner of Patents, *Annual Report for Fiscal Year 1970,* pp. 21 and 26.

See Figure 4-18 in text.

Table 4-11. U.S. patents[1] granted, by assignee and date of grant, 1961-76

Year	All assignees	Assignees: U.S. corporations	U.S. Government	U.S. individuals[2]	Foreign[3]
1961	40,154	27,382	1,460	11,233	79
1962	45,579	31,377	1,276	12,817	109
1963	37,174	25,722	1,017	10,358	77
1964	38,411	26,808	1,174	10,336	93
1965	50,332	35,698	1,522	13,032	80
1966	54,636	39,893	1,512	13,050	181
1967	51,274	36,745	1,726	12,634	169
1968	45,783	33,351	1,458	10,768	206
1969	50,398	37,033	1,810	11,362	193
1970	47,077	34,903	1,761	10,157	256
1971	55,980	40,676	2,135	12,746	423
1972	51,520	36,874	1,762	12,578	306
1973	51,509	36,515	2,078	12,677	239
1974	50,648	35,655	1,729	12,978	286
1975	46,731	33,404	1,882	11,202	243
1976	44,280	32,119	1,807	10,118	236

[1] Due to U.S. inventors.
[2] Comprises patents assigned to U.S. individuals and unassigned patents.
[3] Comprises patents assigned to foreign corporations, governments, and individuals.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *OTAF Special Report—All Technologies* (May 1977), unpublished; U.S. Commissioner of Patents, *Annual Report for Fiscal Year 1970*, pp. 21 and 26; and Office of Technology Assessment and Forecast, unpublished data.

See Figure 4-19 in text.

Table 4-12. U.S. patents granted[1], by product field and date of grant, 1963-75

Product field	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Average rate of change from 1963 to 1975, percent per year[2]
Food and kindred products	418	439	452	484	443	469	536	519	692	712	614	581	622	3.9
Textile mill products	426	360	358	454	480	453	599	550	625	648	517	448	419	2.3
Chemicals and allied products, except drugs	4,635	4,706	5,638	7,585	7,736	6,530	7,248	6,458	6,008	8,802	6,894	7,049	7,546	2.8
Basic industrial inorganic & organic chemicals	2,784	2,977	3,275	4,191	4,307	3,808	4,291	3,733	3,311	4,973	3,757	4,001	4,302	2.4
Industrial inorganic chemicals	669	664	801	849	917	979	983	770	846	1,010	798	913	930	1.9
Industrial organic chemicals	2,338	2,585	2,826	3,710	3,743	3,146	3,624	3,228	2,770	4,323	3,256	3,398	3,650	2.3
Plastics materials and synthetic resins, rubber, and fibers	959	877	1,471	2,123	2,198	1,789	1,857	1,662	1,393	2,189	1,658	1,739	1,764	2.8
Agricultural chemicals	475	486	432	683	645	444	586	530	582	769	699	804	1,038	5.5
All other chemicals	460	408	518	692	714	589	651	642	800	1,063	885	720	726	4.8
Soap, detergents, and cleaning preparations; perfumes, cosmetics, and other toilet preparations	97	86	144	204	261	131	176	218	269	260	254	246	250	6.7
Paints, varnishes, lacquers, enamels, and allied products	37	17	32	52	38	54	60	41	45	54	66	59	64	5.9
Miscellaneous chemical products	392	368	415	536	496	488	510	454	577	763	653	509	519	0.9
Drugs	628	627	580	824	782	578	741	639	657	943	791	920	1,140	4.0
Oil and gas extraction, and petroleum refining and related industries	576	636	784	950	817	782	792	789	768	810	803	894	761	1.4
Rubber and miscellaneous plastics products	1,986	1,948	2,405	2,805	2,775	2,552	2,828	2,442	2,881	2,675	2,473	2,568	2,481	1.2
Stone, clay, glass, and concrete products	805	802	983	1,225	1,103	963	1,191	1,213	1,553	1,263	1,145	1,339	1,099	3.1
Primary metals and metal forgings	431	526	558	627	630	534	524	498	585	594	631	690	571	1.7
Primary ferrous metals industries	325	363	384	429	471	388	383	371	412	395	445	489	435	1.8
Primary and secondary nonferrous metals industries	197	294	325	358	363	322	300	262	320	379	388	385	308	2.2
Fabricated metal products; except machinery, transportation equipment, forgings, & ordnance	5,466	5,595	7,526	7,721	7,262	6,608	6,882	5,976	7,430	6,402	6,826	6,864	6,216	0.3
Machinery, except electrical	12,739	13,146	16,905	17,604	16,322	14,497	15,454	13,944	17,129	15,085	15,822	15,524	13,734	0.3
Engines and turbines	901	903	1,108	1,102	960	898	840	773	913	862	1,024	1,078	1,114	0.5
Farm and garden machinery and equipment	1,416	1,509	1,871	1,760	1,619	1,415	1,543	1,434	1,814	1,538	1,658	1,694	1,500	0.1
Construction, mining, and materials handling machinery and equipment	2,369	2,366	3,377	3,181	3,090	2,404	2,604	2,375	3,030	2,517	2,822	2,829	2,570	-0.2
Metalworking machinery and equipment	1,242	1,414	1,686	1,516	1,442	1,287	1,582	1,296	1,727	1,353	1,449	1,481	1,140	-0.4
Office, computing, and accounting machines	1,199	1,333	1,763	2,068	1,935	1,576	1,954	1,766	2,403	2,266	2,009	1,890	1,597	2.4
Other nonelectrical machinery	7,853	8,075	10,186	11,218	10,100	9,336	9,436	8,441	10,249	9,029	9,540	9,330	8,359	0.0
Special industry machinery, except metalworking machinery	2,963	3,164	3,697	4,496	3,982	3,492	3,684	3,386	4,061	3,604	3,598	3,555	3,240	0.1
General industrial machinery and equipment	4,193	4,185	5,439	5,757	5,292	4,978	4,857	4,328	5,204	4,546	5,054	4,767	4,277	-0.3
Refrigeration and service industry machinery	1,323	1,150	1,457	1,550	1,370	1,232	1,264	1,019	1,468	1,277	1,265	1,315	1,184	-0.7

(Continued)

Table 4-12. (Continued)

Product field	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Average rate of change from 1963 to 1975, percent per year[2]
Miscellaneous machinery, except electrical	557	633	807	724	771	726	790	783	999	894	943	988	803	3.3
Electrical equipment, except communication equipment; and electrical measuring instruments	3,918	4,194	6,084	6,799	6,255	5,412	6,021	5,842	6,879	5,540	5,686	5,148	4,537	0.5
Electrical transmission and distribution equipment and electrical measuring instruments	978	1,301	2,132	2,338	2,059	1,654	1,925	1,928	2,335	1,763	1,933	1,673	1,324	0.7
Electrical industrial apparatus	1,271	1,218	1,841	2,085	1,940	1,681	1,989	1,896	2,118	1,669	1,598	1,359	1,189	-0.5
Other electrical machinery, equipment and supplies	2,194	2,203	2,929	3,268	3,054	2,732	2,921	2,786	3,264	2,738	2,761	2,616	2,481	0.4
Household appliances	888	867	1,039	1,131	1,062	1,022	961	790	1,026	913	876	853	792	-1.3
Electric lighting and wiring equipment	531	547	779	938	808	659	717	706	832	689	817	752	614	0.8
Miscellaneous electrical machinery, equipment, and supplies	766	781	1,095	1,192	1,176	1,045	1,239	1,283	1,397	1,129	1,061	1,003	1,065	1.6
Communication equipment & electronic components	3,681	4,080	6,093	6,530	5,747	5,340	6,497	6,512	7,761	6,407	6,551	5,771	5,460	2.4
Radio and television receiving equipment, except communication types	515	547	937	990	830	866	1,059	1,066	1,284	1,111	977	904	909	3.4
Electronic components and accessories and communication equipment	3,621	4,042	5,970	6,396	5,661	5,232	6,412	6,435	7,687	6,337	6,509	5,713	5,411	2.5
Transportation equipment, except aircraft; and ordnance	2,316	2,395	3,138	2,895	2,765	2,686	2,583	2,396	2,878	2,627	3,331	3,255	2,943	1.6
Motor vehicles and motor vehicle equipment	1,160	1,122	1,580	1,396	1,426	1,366	1,359	1,290	1,486	1,342	1,682	1,764	1,687	2.6
Guided missiles and space vehicles and parts	334	360	433	495	380	333	297	253	267	277	326	268	246	-4.0
Other transportation equipment	811	828	1,159	1,065	1,009	1,010	940	953	1,115	993	1,130	1,188	992	1.5
Ship and boat building and repairing	293	282	361	313	344	345	343	311	333	314	364	401	312	1.1
Railroad equipment	371	426	624	580	510	536	460	465	604	494	572	563	451	0.9
Motorcycles, bicycles, and parts	85	82	103	92	111	65	66	75	92	87	79	90	73	-1.1
Miscellaneous transportation equipment	400	360	610	575	533	512	455	489	544	519	601	532	522	1.5
Ordnance, except missiles; and tanks	301	353	403	331	331	341	292	220	391	352	598	349	327	1.5
Aircraft and parts	699	720	833	741	684	679	691	658	824	692	781	841	821	0.9
Professional and scientific instruments, except electrical measuring instruments	3,467	3,422	4,775	5,205	4,583	4,513	5,470	5,678	6,518	5,852	6,003	6,014	5,484	3.9

[1] Patents due to U.S. inventors, based on original references in Patent Office files.
[2] Obtained from the least-squares line through the data, for each product field.

NOTE: Detail may not add to totals because of multiple counting.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *U.S. Patent Activity in Fifty-Two Standard Industrial Classification Categories, 1963-75, Considering Original Reference Patent Classification Only.* (A study commissioned specifically for this report.)

See Figure 4-20 in text.

Table 4-13. Sources of invention for U.S. patents,[1] by product field, 1965 and 1975

Product field	Percent foreign inventors		Number of patents granted: U.S. inventors		Number of patents granted: Foreign inventors	
	1965	1975	1965	1975	1965	1975
Food and kindred products	20	39	452	622	112	392
Textile mill products	25	41	358	419	121	297
Chemicals and allied products, except drugs	27	41	5,638	7,546	2,101	5,330
Basic industrial inorganic & organic chemicals	31	44	3,275	4,302	1,450	3,345
Industrial inorganic chemicals	30	38	801	930	340	569
Industrial organic chemicals	31	45	2,826	3,650	1,248	2,965
Plastics materials and synthetic resins, rubber, and fibers	21	39	1,471	1,764	390	1,138
Agricultural chemicals	35	44	432	1,038	229	815
All other chemicals	17	30	518	726	107	316
Soap, detergents, and cleaning preparations; perfumes, cosmetics, and other toilet preparations	18	35	144	250	32	136
Paints, varnishes, lacquers, enamels, and allied products	9	30	32	64	3	27
Miscellaneous chemical products	15	27	415	519	76	196
Drugs	42	46	580	1,140	423	968
Oil and gas extraction, and petroleum refining and related industries	7	16	784	761	62	150
Rubber and miscellaneous plastics products	16	33	2,405	2,481	452	1,210
Stone, clay, glass, and concrete products	16	34	983	1,099	193	556
Primary metals and metal forgings	28	44	558	571	217	454
Primary ferrous metals industries	28	44	384	435	148	346
Primary and secondary nonferrous metals industries	29	45	325	308	132	251
Fabricated metal products; except machinery, transportation equipment, forgings, & ordnance	16	30	7,526	6,216	1,434	2,630
Machinery, except electrical	21	37	16,905	13,734	4,596	7,903
Engines and turbines	29	41	1,108	1,114	457	766
Farm and garden machinery and equipment	18	27	1,871	1,500	401	561
Construction, mining, and materials handling machinery and equipment	18	30	3,377	2,570	719	1,112
Metalworking machinery and equipment	21	39	1,686	1,140	443	733
Office, computing, and accounting machines	18	35	1,763	1,597	398	865
Other nonelectrical machinery	23	38	10,186	8,359	2,979	5,053
Special industry machinery, except metalworking machinery	26	43	3,697	3,240	1,281	2,410
General industrial machinery and equipment	21	35	5,439	4,277	1,488	2,329
Refrigeration and service industry machinery	16	31	1,457	1,184	275	522
Miscellaneous machinery, except electrical	20	31	807	803	200	359

(Continued)

Table 4-13. (Continued)

Product field	Percent foreign inventors		Number of patents granted			
			U.S. inventors		Foreign inventors	
	1965	1975	1965	1975	1965	1975
Electrical equipment, except communication equipment; and electrical measuring instruments	18	34	6,084	4,537	1,297	2,344
Electrical transmission and distribution equipment and electrical measuring instruments	16	32	2,132	1,324	403	636
Electrical industrial apparatus	20	41	1,841	1,189	463	820
Other electrical machinery, equipment and supplies	18	32	2,929	2,481	650	1,189
Household appliances	18	29	1,039	792	222	316
Electric lighting and wiring equipment	18	37	779	614	175	360
Miscellaneous electrical machinery, equipment, and supplies	18	32	1,095	1,065	248	511
Communication equipment & electronic components	18	34	6,093	5,460	1,315	2,767
Radio and television receiving equipment, except communication types	18	36	937	909	204	522
Electronic components and accessories and communication equipment	18	33	5,970	5,411	1,288	2,715
Transportation equipment, except aircraft; and ordnance	23	37	3,138	2,943	921	1,739
Motor vehicles and motor vehicle equipment	26	41	1,580	1,687	543	1,186
Guided missiles and space vehicles and parts	24	34	433	246	139	127
Other transportation equipment	22	38	1,159	992	324	599
Ship and boat building and repairing	17	32	361	312	72	146
Railroad equipment	24	46	624	451	202	390
Motorcycles, bicycles, and parts	34	49	103	73	53	69
Miscellaneous transportation equipment	27	41	610	522	221	359
Ordnance, except missiles; and tanks	17	27	403	327	83	123
Aircraft and parts	30	45	833	821	353	659
Professional and scientific instruments, except electrical measuring instruments	19	34	4,775	5,484	1,139	2,847

[1] Based on original references in Patent Office files.

NOTE: Detail may not add to totals because of multiple counting.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *U.S. Patent Activity in Fifty-Two Standard Industrial Classification Categories, 1963-75, Considering Original Reference Patent Classification Only* (a study commissioned specifically for this report).

See Table 4-21 in text.

Table 4-14. Ownership of U. S. patents[1] in each product field, for patents granted in 1965 and 1975

Product field	Percent U.S. corporations		Percent U.S. Government		Percent U.S. individuals	
	1965	1975	1965	1975	1965	1975
Food and kindred products	71	77	5	5	23	17
Textile mill products	84	77	3	9	12	13
Chemicals and allied products, except drugs	93	90	3	4	4	5
Basic industrial inorganic & organic chemicals	93	91	3	4	3	4
Industrial inorganic chemicals	87	85	8	6	5	8
Industrial organic chemicals	94	92	3	4	3	4
Plastics materials and synthetic resins, rubber, and fibers	95	93	2	2	3	5
Agricultural chemicals	87	89	3	2	10	8
All other chemicals	87	81	6	11	7	8
Soap, detergents, and cleaning preparations; perfumes, cosmetics, and other toilet preparations	85	87	5	1	10	10
Paints, varnishes, lacquers, enamels, and allied products	88	86	3	5	9	9
Miscellaneous chemical products	88	79	6	14	6	6
Drugs	89	89	2	3	8	7
Oil and gas extraction, and petroleum refining and related industries	92	90	0	2	7	7
Rubber and miscellaneous plastics products	68	71	2	2	29	26
Stone, clay, glass, and concrete products	77	78	2	2	21	19
Primary metals and metal forgings	79	75	4	6	17	18
Primary ferrous metals industries	80	76	2	5	18	18
Primary and secondary nonferrous metals industries	79	77	6	7	14	14
Fabricated metal products; except machinery, transportation equipment, forgings, & ordnance	64	64	2	2	34	34
Machinery, except electrical	69	70	2	2	29	28
Engines and turbines	65	69	5	3	30	28
Farm and garden machinery and equipment	53	56	1	1	46	43
Construction, mining, and materials handling machinery and equipment	61	63	1	1	38	36
Metalworking machinery and equipment	69	65	1	1	30	33
Office, computing, and accounting machines	83	82	3	3	15	14
Other nonelectrical machinery	71	71	1	2	27	27
Special industry machinery, except metalworking machinery	74	75	2	1	24	23
General industrial machinery and equipment	69	69	1	2	29	29
Refrigeration and service industry machinery	66	64	1	1	33	35
Miscellaneous machinery, except electrical	68	67	1	2	31	30

(Continued)

Table 4-14. (Continued)

Product field	Percent U.S. corporations 1965	1975	Percent U.S. Government 1965	1975	Percent U.S. individuals 1965	1975
Electrical equipment, except communication equipment; and electrical measuring instruments	79	77	3	5	17	17
Electrical transmission and distribution equipment and electrical measuring instruments	82	76	5	9	13	15
Electrical industrial apparatus	84	84	3	3	12	12
Other electrical machinery, equipment and supplies	75	76	2	3	22	20
Household appliances	67	69	1	1	32	29
Electric lighting and wiring equipment	77	77	2	4	21	19
Miscellaneous electrical machinery, equipment, and supplies	81	81	4	4	15	14
Communication equipment & electronic components	81	76	7	9	12	14
Radio and television receiving equipment, except communication types	83	78	6	9	11	12
Electronic components and accessories and communication equipment	81	76	7	9	12	14
Transportation equipment, except aircraft; and ordnance	59	59	7	7	33	34
Motor vehicles and motor vehicle equipment	63	65	2	1	35	34
Guided missiles and space vehicles and parts	68	73	16	15	16	12
Other transportation equipment	64	58	2	2	34	38
Ship and boat building and repairing	54	49	2	6	44	44
Railroad equipment	81	78	1	0	17	22
Motorcycles, bicycles, and parts	79	70	0	1	21	29
Miscellaneous transportation equipment	66	62	1	1	33	37
Ordnance, except missiles; and tanks	38	39	32	42	30	20
Aircraft and parts	61	67	6	4	33	29
Professional and scientific instruments, except electrical measuring instruments	68	67	4	6	28	27

[1] Due to U.S. inventors, based on original references in Patent Office files. Foreign-owned patents are not shown.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *U.S. Patent Activity in Fifty-Two Standard Industrial Classification Categories, 1963-75.* (A study commissioned specifically for this report)

See Tables 4-22, 4-23, and 4-24 in text.

Table 4-15. U.S. patents granted, by inventor and date of application, 1965-73

Year	All U.S. patents	To U.S. residents	To foreign residents
1965	54,820	42,189	12,631
1966	59,604	44,955	14,649
1967	59,958	44,112	15,846
1968	62,866	45,250	17,616
1969	65,707	46,278	19,429
1970	65,658	45,624	20,034
1971	65,938	45,268	20,670
1972	62,586	41,904	20,682
1973	64,482	41,557	22,925

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *OTAF Special Report—All Technologies* (May 1977), unpublished.

See Figure 4-26 in text.

Table 4-16. U.S. patents[1] granted, by assignee and date of application, 1965-73

Year	All assignees	Assignees			
		U.S. corporations	U.S. Government	U.S. individuals[2]	Foreign[3]
1965	42,189	30,143	1,423	10,475	148
1966	44,955	32,795	1,463	10,483	214
1967	44,112	31,882	1,551	10,462	217
1968	45,250	32,858	1,688	10,440	264
1969	46,278	33,355	1,786	10,832	305
1970	45,624	32,204	1,584	11,552	284
1971	45,268	31,947	1,550	11,514	257
1972	41,904	29,928	1,474	10,293	209
1973	41,557	29,436	1,338	10,576	207

[1] Due to U.S. inventors.
[2] Comprises patents assigned to U.S. individuals and unassigned patents.
[3] Comprises patents assigned to foreign corporations, governments, and individuals.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *OTAF Special Report—All Technologies* (May 1977), unpublished.

See Figure 4-27 in text.

Table 4-17. U.S. patents granted,[1] by product field and date of application, 1963-73

Product field	1965	1966	1967	1968	1969	1970	1971	1972	1973
Food and kindred products	472	492	476	499	533	646	552	433	370
Textile mill products	448	437	505	471	480	519	482	376	302
Chemicals and allied products, except drugs	5,806	6,238	6,091	6,078	6,254	6,157	6,086	5,447	4,938
Basic industrial inorganic & organic chemicals	3,406	3,674	3,567	3,604	3,605	3,446	3,339	3,039	2,723
Industrial inorganic chemicals	747	824	794	797	787	763	778	714	621
Industrial organic chemicals	2,906	3,168	3,065	3,103	3,088	2,945	2,858	2,564	2,307
Plastics materials and synthetic resins, rubber, and fibers	1,461	1,504	1,403	1,373	1,431	1,481	1,539	1,358	1,307
Agricultural chemicals	443	527	538	540	624	596	592	582	656
All other chemicals	618	643	658	684	738	714	769	612	434
Soap, detergents, and cleaning preparations; perfumes, cosmetics, and other toilet preparations	208	196	191	201	229	234	269	226	135
Paints, varnishes, lacquers, enamels, and allied products	41	42	39	37	39	44	68	51	55
Miscellaneous chemical products	435	473	515	519	560	507	527	409	297
Drugs	602	679	630	647	735	707	693	654	727
Oil and gas extraction, and petroleum refining and related industries	570	711	738	758	752	756	735	619	610
Rubber and miscellaneous plastics products	2,284	2,390	2,405	2,337	2,475	2,346	2,319	2,174	1,769
Stone, clay, glass, and concrete products	965	1,000	1,042	1,030	1,137	1,133	1,086	1,010	868
Primary metals and metal forgings	486	532	503	507	481	556	536	484	486
Primary ferrous metals industries	338	389	367	385	331	377	397	349	364
Primary and secondary nonferrous metals industries	281	320	299	256	295	337	324	266	268
Fabricated metal products; except machinery, transportation equipment, forgings, & ordnance	5,782	6,391	6,231	6,217	6,186	6,090	6,008	5,620	5,059
Machinery, except electrical	13,280	14,298	13,770	13,988	14,152	13,906	13,875	12,669	11,697
Engines and turbines	692	906	817	804	809	848	917	866	894
Farm and garden machinery and equipment	1,456	1,521	1,388	1,448	1,424	1,404	1,419	1,398	1,305
Construction, mining, and materials handling machinery and equipment	2,337	2,543	2,549	2,618	2,578	2,392	2,473	2,286	2,160
Metalworking machinery and equipment	1,304	1,270	1,323	1,380	1,304	1,200	1,254	1,128	1,021
Office, computing, and accounting machines	1,622	1,583	1,495	1,470	1,806	1,865	1,689	1,630	1,474
Other nonelectrical machinery	8,169	9,042	8,556	8,631	8,702	8,477	8,513	7,528	6,989
Special industry machinery, except metalworking machinery	3,211	3,556	3,356	3,324	3,385	3,311	3,215	2,788	2,564
General industrial machinery and equipment	4,343	4,630	4,390	4,492	4,459	4,364	4,440	3,954	3,714
Refrigeration and service industry machinery	1,051	1,268	1,165	1,234	1,178	1,144	1,145	1,097	1,041
Miscellaneous machinery, except electrical	649	728	721	739	848	815	867	769	684
Electrical equipment, except communication equipment; and electrical measuring instruments	4,844	5,318	5,118	5,197	5,085	5,072	4,831	4,531	4,331
Electrical transmission and distribution equipment and electrical measuring instruments	1,570	1,709	1,653	1,681	1,657	1,605	1,566	1,517	1,408
Electrical industrial apparatus	1,519	1,611	1,503	1,517	1,500	1,539	1,442	1,240	1,235
Other electrical machinery, equipment and supplies	2,354	2,684	2,582	2,609	2,473	2,588	2,354	2,278	2,155
Household appliances	818	940	898	878	827	849	781	713	684
Electric lighting and wiring equipment	631	683	675	645	615	643	621	683	604
Miscellaneous electrical machinery, equipment, and supplies	899	1,056	1,003	1,080	1,023	1,089	946	875	862

(Continued)

Table 4-17. (Continued)

Product field	1965	1966	1967	1968	1969	1970	1971	1972	1973
Communication equipment & electronic components	5,209	5,450	5,133	5,242	5,687	5,505	5,258	4,971	4,683
Radio and television receiving equipment, except communication types	789	861	835	845	956	900	783	787	769
Electronic components and accessories and communication equipment	5,118	5,368	5,058	5,181	5,610	5,443	5,223	4,934	4,633
Transportation equipment, except aircraft; and ordnance	2,178	2,577	2,520	2,701	2,600	2,646	2,706	2,544	2,452
Motor vehicles and motor vehicle equipment	1,143	1,280	1,323	1,348	1,339	1,389	1,489	1,483	1,379
Guided missiles and space vehicles and parts	267	362	273	242	236	255	220	192	209
Other transportation equipment	802	985	871	1 089	1,046	1,019	969	881	892
Ship and boat building and repairing	245	321	310	375	339	328	329	280	285
Railroad equipment	418	527	438	530	532	507	451	444	416
Motorcycles, bicycles, and parts	79	71	62	80	92	79	69	65	76
Miscellaneous transportation equipment	438	490	405	535	529	537	505	440	459
Ordnance, except missiles; and tanks	275	288	325	372	343	349	345	271	241
Aircraft and parts	525	670	680	697	758	719	687	662	688
Professional and scientific instruments, except electrical measuring instruments	4,491	4,585	4,701	4,801	4,992	5,081	5,150	4,836	4,679

[1] Patents due to U.S. inventors, based on original references in Patent Office files.

NOTE: Detail may not add to totals because of multiple counting.

SOURCE: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, *U.S. Patent Activity in Fifty-Two Standard Industrial Classification Categories, 1963-75.* (A study commissioned specifically for this report)

See Figure 4-28 in text.

Table 4-18. Distribution of major U.S. innovations by size of company, 1953-73

Period	Total	Size of company: Up to 100 employees	100-1,000 employees	1,000-5,000 employees	5,000-10,000 employees	10,000 or more employees
		Percent distribution				
1953-73	100	23	24	13	5	34
1953-59	100	23	26	14	8	29
1960-66	100	27	23	14	5	31
1967-73	100	20	23	12	3	43
		Number of innovations				
1953-73	310	72	75	41	16	106
1953-59	102	23	27	14	8	30
1960-66	107	29	25	15	5	33
1967-73	101	20	23	12	3	43

NOTE: Detail may not add to totals because of rounding.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1976, based on Appendix D.

See Figure 4-30 and Table 4-31 in text.

Table 4-19. Distribution of major U.S. innovations by industry group, 1953-73

Period	Total	Manufacturing industries (R&D intensity groups)[1] Group I	Group II	Group III	Nonmanufacturing industries[2]
	Percent distribution				
1953-73	100	59	21	9	11
1953-59 ...	100	48	25	16	12
1960-66 ...	100	64	19	5	12
1967-73 ...	100	63	21	8	8
	Number of innovations				
1953-73	310	182	66	29	33
1953-59 ...	102	49	25	16	12
1960-66 ...	107	69	20	5	13
1967-73 ...	101	64	21	8	8

[1] See Figure 4-17 and related text for an explanation of these groups.
[2] Limited to those nonmanufacturing industries reporting significant levels of R&D.

NOTE: Detail may not add to totals because of rounding.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation,* 1976, based on Appendix D.

See Figure 4-32 in text.

Table 4-20. Major U.S. innovations by industry, 1953-73

Industry	Number of innovations	Percent of total
Total	310	100
Manufacturing industries	277	89
Electrical equipment and communication	53	17
Chemicals and allied products	45	15
Machinery	44	14
Professional and scientific instruments	29	9
Stone, clay, and glass products	18	6
Motor vehicles and other transportation equipment	18	6
Primary metals	17	5
Rubber products	15	5
Aircraft and missiles	11	4
Fabricated metal products	10	3
Petroleum refining and extraction	5	2
Textiles and apparel	4	1
Paper and allied products	4	1
Food and kindred products	2	1
Lumber, wood products, and furniture	2	1
Nonmanufacturing industries	33	11

NOTE: Detail may not add to totals because of rounding.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation,* 1976, based on Appendix D.

See Figure 4-33 in text.

Table 4-21. Estimated radicalness of major U.S. innovations, 1953-73

Radicalness classification	1953-73 period	1953-59	1960-66	1967-73
	Percent distribution			
Total	100	100	100	100
Radical breakthrough	26	36	26	16
Major technological shift	28	17	31	35
Improvement	38	39	37	40
Imitation or no new technology	8	8	6	10
	Number of innovations			
Total	250	75	94	81
Radical breakthrough	64	27	24	13
Major technological shift	70	13	29	28
Improvement	96	29	35	32
Imitation or no new technology	20	6	6	8

NOTE: Detail may not add to totals because of rounding.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1976, based on Appendix D.

See Figure 4-36 in text.

Table 4-22. Estimated radicalness of major U.S. innovations by industry group, 1953-73

Radicalness classification and industry group	1953-73 period	1953-59	1960-66	1967-73
	Percent distribution			
Total	100	100	100	100
Manufacturing industries	90	89	88	93
Group I	59	51	63	62
Radical breakthrough	15	19	19	6
Major technological shift	21	13	22	27
Improvement	20	17	20	23
Imitation or no new technology	2	1	1	5
Group II	22	25	20	21
Radical breakthrough	5	5	4	6
Major technological shift	4	3	5	5
Improvement	9	12	7	7
Imitation or no new technology	4	5	3	2
Group III	9	13	5	10
Radical breakthrough	3	5	1	2
Major technological shift	1	0	1	1
Improvement	5	7	3	5
Imitation or no new technology	1	1	0	1
Nonmanufacturing industries	10	11	12	7
Radical breakthrough	3	7	1	1
Major technological shift	2	1	2	1
Improvement	4	3	6	4
Imitation or no new technology	1	0	2	1
	Number of innovations			
Total	250	75	94	81
Manufacturing industries	225	67	83	75
Group I	147	38	59	50
Radical breakthrough	37	14	18	5
Major technological shift	53	10	21	22
Improvement	51	13	19	19
Imitation or no new technology	6	1	1	4
Group II	55	19	19	17
Radical breakthrough	13	4	4	5
Major technological shift	11	2	5	4
Improvement	22	9	7	6
Imitation or no new technology	9	4	3	2
Group III	23	10	5	8
Radical breakthrough	7	4	1	2
Major technological shift	2	0	1	1
Improvement	12	5	3	4
Imitation or no new technology	2	1	0	1
Nonmanufacturing industries	25	8	11	6
Radical breakthrough	7	5	1	1
Major technological shift	4	1	2	1
Improvement	11	2	6	3
Imitation or no new technology	3	0	2	1

NOTE: Detail may not add to totals because of rounding.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1976, based on Appendix D.

See Figure 4-37 in text.

Table 4-23. Sources of technology underlying major U.S. innovations, 1953-73

Source	Frequency[1]	Percent of innovations
Applied research	225	89
Internally generated[2]	215	85
External only	10	4
Basic research	122	48
Internally generated[2]	91	36
External only	31	12
Technology transfer[3]	83	33
License	13	5
Purchase of patent or "know-how"	6	2
Acquisition or merger	0	0
Corporate R&D activity	141	56
Other	36	14

[1] Multiple responses were accepted; 254 innovations are included.

[2] Wholly or partly internal.

[3] From an existing product of the same company.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation,* 1976, based on Appendix D.

See Figure 4-38 in text.

Table 4-24. Sources of technology underlying major U.S. innovations by industry group, 1953-73

Source of underlying technology	Total all industry groups	Manufacturing industries: Total	Group I	Group II	Group III	Nonmanufacturing industries
	Percent of innovations in each group					
Total	([3])	([3])	([3])	([3])	([3])	([3])
Applied research	89	90	91	85	87	80
Internally generated[1]	85	86	88	83	74	76
External only	4	4	3	2	13	4
Basic research	48	48	53	39	34	52
Internally generated[1]	36	35	40	28	17	44
External only	12	13	13	11	17	8
License	5	5	5	7	0	4
Acquisition or merger	0	0	0	0	0	0
Technology transfer[2]	33	33	36	31	22	28
Corporate R&D activity	56	59	58	59	65	24
Purchase of patent or "know-how"	2	3	3	0	4	0
Other	14	15	14	13	22	8
	Number of innovations					
Total	254	229	152	54	23	25
Applied research	225	205	139	46	20	20
Internally generated[1]	215	196	134	45	17	19
External only	10	9	5	1	3	1
Basic research	122	109	80	21	8	13
Internally generated[1]	91	80	61	15	4	11
External only	31	29	19	6	4	2
License	13	12	8	4	0	1
Acquisition or merger	0	0	0	0	0	0
Technology transfer[2]	83	76	54	17	5	7
Corporate R&D activity	141	135	88	32	15	6
Purchase of patent or "know-how"	6	6	5	0	1	0
Other	36	34	22	7	5	2

[1] Wholly or partly internally generated.
[2] From an existing product of the same company.
[3] Multiple responses were accepted; therefore these columns add to more than 100 percent.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation,* 1976, based on Appendix D.

See Figure 4-39 in text.

Table 4-25. Sources of underlying technology and estimated radicalness of innovations, 1953-73[1]

Source of underlying technology	Radical break-through	Major technological shift	Improve-ment	Imitation or no new technology
	Percent of innovations in each radicalness category			
Total	([4])	([4])	([4])	([4])
Applied research	86	93	91	60
Internally generated[2]	81	87	88	60
External only	5	6	3	0
Basic research	66	46	44	20
Internally generated[2]	47	39	31	10
External only	19	7	13	10
License	3	7	6	0
Acquisition or merger	0	0	0	0
Technology transfer[3]	28	33	38	25
Corporate R&D activity	52	57	60	25
Purchase of patent or "know-how"	5	1	2	0
Other	14	13	9	40
	Number of innovations			
Total	64	70	96	20
Applied research	55	65	87	12
Internally generated[2]	52	61	84	12
External only	3	4	3	0
Basic research	42	32	42	4
Internally generated[2]	30	27	30	2
External only	12	5	12	2
License	2	5	6	0
Acquisition or merger	0	0	0	0
Technology transfer[3]	18	23	36	5
Corporate R&D activity	33	40	58	5
Purchase of patent or "know-how"	3	1	2	0
Other	9	9	9	8

[1] Based on 250 innovations.
[2] Wholly or partly internally generated.
[3] From an existing product of the same company.
[4] Multiple responses were accepted; therefore these columns add to more than 100 percent.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1976, based on Appendix D.

See Figure 4-40 in text.

Table 4-26. Major U.S. innovations assisted by public grants or contracts, by industry group, 1953-73

Industry group	Total	Public funds	No public funds
	Percent distribution		
Total	100	22	78
Manufacturing industries	100	21	79
Group I	100	24	76
Group II	100	13	87
Group III	100	13	87
Nonmanufacturing industries	100	36	64
	Number of innovations		
Total	248	55	193
Manufacturing industries	223	46	177
Group I	148	36	112
Group II	52	7	45
Group III	23	3	20
Nonmanufacturing industries	25	9	16

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1976, based on Appendix D.

See Figure 4-41 in text.

Table 4-27. Sources of invention underlying major U.S. innovations, 1953-73

Source	Frequency[1]	Percent of innovations
Same profit center that produced innovation	152	62
Same enterprise but not same profit center	59	24
Independent inventor	46	19
Government laboratory	13	5
Government publication	1	0
Professional/scientific publication	5	2
University	19	8

[1] Multiple responses were accepted; 246 innovations are included.

SOURCE: Gellman Research Associates, Inc., *Indicators of International Trends in Technological Innovation*, 1976, based on Appendix D.

See Figure 4-42 in text.

Table 5-1. Annual average percent changes in science and engineering employment compared to other economic and manpower variables, 1950-74

Indicator	1950-74 period	1950-63	1963-70	1970-74
Scientists and engineers combined	4.6	6.6	3.2	0.7
Scientists	5.3	7.0	4.8	1.4
Engineers	4.3	6.5	2.5	0.3
Nonfarm workers[1]	2.3	1.7	3.3	2.5
GNP[2]	3.5	3.5	3.8	3.0
FRB[3] Index	4.3	4.2	4.9	4.0

[1] Nonfarm wage and salary workers.
[2] Gross National Product (in constant 1972 dollars).
[3] Federal Reserve Board Index of Industrial Production.

SOURCE: Bureau of Labor Statistics, unpublished data, and Executive Office of the President, *Economic Report of the President, 1976.*

See Figure 5-1 in text.

Table 5-2. Scientists and engineers employed in universities and colleges by field of employment, 1965-76

Field of employment	January 1965	1967	1969	1971	1973	1974	1975	1976
All scientists and engineers	178,904	212,855	231,756	257,904	265,208	269,265	280,635	289,204
Engineers	21,681	25,253	25,387	27,130	27,530	27,147	27,845	28,296
Aeronautical and astronautical	1,127	1,360	1,357	1,469	1,480	1,191	1,094	1,127
Chemical	1,571	1,565	1,735	1,843	1,761	1,724	1,856	1,833
Civil	3,145	3,660	3,894	4,129	4,487	4,544	4,853	4,995
Electrical	5,478	6,563	6,803	6,885	6,941	6,475	6,758	6,915
Mechanical	4,108	4,638	4,812	5,387	5,188	4,959	5,286	5,290
Other engineers	6,252	7,467	6,786	7,417	7,673	8,254	7,998	8,136
Physical scientists	25,485	31,354	33,698	35,943	37,150	38,214	38,682	39,959
Chemists	10,684	12,961	14,201	14,688	15,286	16,063	16,134	16,593
Earth scientists[1]	4,005	5,111	5,549	6,500	6,935	7,627	7,842	8,462
Ptysicists	9,132	11,127	11,766	12,195	12,184	12,135	12,319	12,240
Other physical scientists	1,664	2,155	2,182	2,560	2,745	2,389	2,387	2,664
Mathematicians and computer scientists	13,680	17,776	22,495	24,548	24,770	27,096	28,414	29,798
Life scientists	75,775	87,347	97,206	110,274	112,667	111,314	115,254	115,723
Agricultural	13,507	14,950	15,150	18,039	15,278	13,619	14,627	14,154
Biological	24,281	27,419	29,257	31,808	33,629	35,723	38,192	39,734
Medical	37,987	44,978	52,799	60,427	63,760	61,972	62,435	61,835
Psychologists	9,430	11,358	14,780	16,806	18,876	19,962	21,665	22,857
Social scientists[2]	32,853	39,767	38,190	43,203	44,215	45,532	48,775	52,571
Economists	7,932	9,662	10,402	11,263	11,376	12,045	12,667	13,170
Sociologists	6,261	7,558	9,451	11,323	12,483	13,000	14,230	15,159
Political scientists	5,919	7,190	7,919	8,938	9,704	10,005	10,555	11,309
Other social scientists	12,741	15,357	10,418	11,679	10,652	10,482	11,323	12,933

[1] Includes atmospheric scientists and oceanographers.
[2] Excludes historians.

SOURCE: National Science Foundation, *Manpower Resources for Scientific Activities at Universities and Colleges, January 1976,* Detailed Statistical Tables (NSF 76-321), p. 1.

See Figure 5-4 in text.

Table 5-3. Scientists and engineers employed in universities and colleges by level of attainment, 1965-76

Level of attainment	1965	1967	1969	1971	1973	1974	1975	1976
Total[1]	178,904	212,855	231,756	257,904	265,208	269,265	280,635	289,204
Ph.D. and Sc.D.	74,278	88,876	100,790	116,052	124,801	130,961	136,810	139,936
Ed.D. and J.D.	NA	NA	NA	NA	NA	NA	NA	4,371
M.D. and D.D.S.	33,524	38,695	41,734	46,529	47,070	43,803	44,558	45,113
Master's	52,380	63,161	65,720	71,364	68,908	71,162	74,790	75,490
Bachelor's or equivalent	18,722	22,123	23,512	23,959	24,429	23,339	24,477	24,294

[1] Full-time and part-time as of January.

SOURCE: National Science Foundation, unpublished data.

See Figure 5-5 in text.

Table 5-4. Academic scientists and engineers by primary work activity, 1965-76

Primary work activity	1965	1967	1969	1971	1973	1974	1975	1976
Total[1]	178,904	212,855	231,756	257,904	265,208	269,265	280,635	289,204
Teaching	121,991	147,846	160,781	184,966	199,083	207,138	215,776	223,216
Research and development	40,003	44,603	47,118	48,268	46,634	47,375	49,975	50,994
Other activities	16,910	20,406	23,857	24,670	19,491	14,752	14,884	14,994

[1] Full-time and part-time as of January.

SOURCE: National Science Foundation, *Manpower Resources for Scientific Activities at Universities and Colleges, January 1976,* Detailed Statistical Tables (NSF 76-321), p. 1.

See Figure 5-6 in text.

Table 5-5. Tenured faculty as a percent of full-time faculty in a sample of doctorate-level science and engineering departments by selected fields, 1974

Selected fields	Total faculty	Number with tenure	Percent with tenure
All science and engineering fields	28,638	20,051	70
Chemical engineering	891	719	81
Physics	3,356	2,607	78
Electrical engineering	2,082	1,612	77
Botany	636	491	77
Chemistry	3,056	2,355	77
Geology	1,145	858	75
Zoology	914	650	71
Biology	1,969	1,353	69
Economics	2,020	1,362	67
Mathematics	4,064	2,721	67
Biochemistry	1,516	997	66
Microbiology	1,209	784	65
Psychology	2,917	1,836	63
Sociology	1,781	1,066	60
Physiology	1,082	640	59

SOURCE: National Science Foundation, *Young and Senior Science and Engineering Faculty, 1974: Support, Research Participation, and Tenure* (NSF 75-302), pp. 20, 24, and unpublished data.

See Figure 5-8 in text.

Table 5-6. R&D scientists and engineers[1] employed in selected industries by source of support,[2] 1967 and 1975

[In thousands]

Industry	Total		Federally supported		Company-supported[3]	
	1967	1975 (Prel.)	1967	1975 (Prel.)	1967	1975 (Prel.)
Total	367.2	357.5	161.3	108.3	205.9	249.4
Electrical equipment and communication	98.6	91.4	51.9	37.6	46.7	53.8
Aircraft and missiles	100.4	66.8	80.3	45.5	20.1	21.3
Machinery	33.6	44.9	7.8	6.4	25.8	38.5
Chemicals and allied products	36.9	43.4	3.6	2.7	33.3	40.7
Motor vehicles and other transportation equipment	25.2	27.0	6.4	3.7	18.8	23.3

[1] Full-time-equivalent basis as of January.
[2] The distribution by source of support for the individual industries is estimated for 1967.
[3] Includes all non-Federal sources of support.

SOURCE: National Science Foundation, *Research and Development in Industry, 1974* (NSF 76-322), pp. 44, 46.

See Figure 5-11 in text.

Table 5-7. Proportion of time spent in research by full-time doctorate faculty in selected science and engineering fields at a sample of institutions, 1975

Selected fields	Number of depart- ments	Number of faculty	Percent of faculty by proportion of time in research		
			20% or more of time	From 20% to 50% of time	More than 50% of time
Total	1,149	23,720	84	46	38
Biochemistry	66	850	95	26	69
Biology	72	1,813	85	48	37
Botany	35	555	83	48	35
Chemical engineering	68	679	81	53	28
Chemistry	114	2,638	86	40	46
Economics	80	1,822	78	53	25
Electrical engineering	72	1,371	73	45	28
Geology	66	930	87	58	29
Mathematics	102	3,414	80	52	28
Microbiology	73	835	91	38	52
Mining and mineral engineering	15	192	72	43	30
Physics	106	2,923	91	31	60
Physiology	67	1,022	93	28	65
Psychology	100	2,483	84	60	24
Sociology	77	1,418	78	50	28
Zoology	36	775	83	62	21

SOURCE: Frank J. Atelsek and Irene L. Gomberg, *Faculty Research: Level of Activity and Choice of Area*, (Washington, D.C.: American Council on Education, 1976), p. 12.

See Figure 5-12 in text.

Table 5-8. Young[1] doctoral faculty investigators[2] as a percent of all doctoral faculty investigators in a sample of doctorate-granting institutions by selected fields, 1968 and 1974

Selected fields	1968	1974
Total	44	30
Biochemistry	33	19
Biology	33	28
Chemical engineering	39	24
Chemistry	38	22
Economics	45	35
Electrical engineering	53	29
Mathematics	55	38
Microbiology	32	22
Physics	42	20
Physiology	36	28
Psychology	45	40
Sociology	48	44

[1] Those who had held doctorates seven years or less at the time of each study.
[2] Spending 20 percent or more of their time in research.

SOURCE: National Science Foundation, *Young and Senior Science and Engineering Faculty, 1974: Support, Research Participation, and Tenure* (NSF 75-302), based on p. 28.

See Figure 5-13 in text.

Table 5-9. Distribution of doctoral scientists and engineers by field, 1973 and 1975

Field	Number		Percent	
	1973	1975	1973	1975
Total	244,921	277,517	100	100
Physical scientists	53,425	59,267	22	21
Chemists	33,881	38,784	14	14
Physicists and astronomers	19,544	20,483	8	7
Mathematical scientists and computer specialists	16,458	18,204	7	7
Mathematicians	11,984	12,729	5	5
Statisticians	1,531	1,813	1	1
Computer specialists	2,943	3,662	1	1
Life scientists	64,540	72,316	26	26
Biological scientists	41,035	43,754	17	16
Medical scientists	11,612	14,285	5	5
Agricultural scientists	11,893	14,277	5	5
Environmental scientists	11,074	12,783	5	5
Earth scientists	9,142	10,076	4	4
Oceanographers	1,227	1,353	1	(1)
Atmospheric scientists	705	1,353	(1)	(1)
Engineers	37,569	44,425	15	16
Psychologists	28,286	31,613	12	11
Social scientists	32,773	38,251	13	14
Economists	9,678	11,049	4	4
Sociologists and anthropologists	7,455	8,775	3	3
Other social scientists	15,640	18,427	6	7
Field not reported	796	658	(1)	(1)

[1] Less than 0.5 percent.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1975* (NSF 77-309), p. viii.

See Table 5-16 in text.

Table 5-10. Distribution of employed doctoral scientists and engineers by employment sector, 1975

Employment sector	All doctoral scientists and engineers		Doctoral scientists[1]		Doctoral engineers	
	Number	Percent[2]	Number	Percent[2]	N.mber	Percent[2]
Total	262,411	100	219,055	100	43,356	100
Business and industry	65,876	25	43,341	20	22,535	52
Educational institutions	153,249	58	137,943	63	15,306	35
Four-year colleges and universities	147,633	56	132,504	61	15,129	35
Two-year colleges	3,674	1	3,497	2	177	(3)
Elementary and secondary schools	1,942	1	1,942	1	—	—
Hospitals and clinics	7,586	3	7,562	3	24	(3)
Nonprofit organizations	8,510	3	7,277	3	1,233	3
Government	26,755	10	22,538	10	4,217	10
Federal[2]	21,634	8	17,855	8	3,779	9
State	3,110	1	2,883	1	227	1
Other	2,011	1	1,800	1	211	(3)
Other employment sector	86	(3)	86	(3)	—	—
Employment sector unreported	349	—	308	—	41	—

[1] Includes 94 scientists or engineers whose field is unknown.
[2] Excluding those whose employer was unreported.
[3] Includes the military and the Commissioned Corps of the Public Health Service.
[4] Less than 0.5 percent.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1975* (NSF 77-309), pp. 38-41.

See Figure 5-17 in text.

Table 5-11. Doctoral scientists and engineers by age and type of employer, 1975

Age	Business and industry		Four-year colleges and universities		Federal Government[1]	
	Number	Percent	Number	Percent	Number	Percent
Total	65,876	100	147,633	100	21,634	100
Under 30	2,129	3	5,772	4	773	4
30-34	15,117	23	30,862	21	4,121	19
35-39	14,113	21	30,903	21	4,734	22
40-44	10,274	16	23,687	16	3,646	17
45-49	8,090	12	19,833	13	3,081	14
50-54	7,476	11	16,146	11	2,398	11
55-59	4,610	7	10,774	7	1,533	7
60-64	2,734	4	6,461	4	953	4
65 or over	1,224	2	3,094	2	382	2
No report	109	(2)	101	(2)	13	(2)

[1] Includes the military and the Commissioned Corps.
[2] Less than 0.5 percent.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1975* (NSF 77-309), pp. 38-41.

See Figure 5-19 in text.

Table 5-12. Percent distribution of employed doctoral scientists and engineers by primary work activity, 1973 and 1975

Primary work activity[1]	1973	1975
Total	100	100
Research and development	33	33
Basic research	15	15
Applied research	14	13
Development	4	5
Management or administration	19	21
Of R&D	11	11
Other than R&D	8	9
Teaching	39	37
Other	9	10

[1] Primary work activity is defined as that type of work occupying the largest portion of time.

NOTE: Percents may not add to 100 because of rounding.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1975* (NSF 77-309), based on pp. 44-47 and unpublished data.

See Figure 5-20 in text.

Table 5-13. Distribution of employed doctoral scientists and engineers by primary work activity, 1975

Primary work activity[1]	All doctoral scientists and engineers		Scientists[2]		Engineers	
	Number	Percent[3]	Number	Percent[3]	Number	Percent[3]
Total	262,411	100	219,055	100	43,356	100
Research & development	84,510	33	67,677	32	16,833	39
Basic research	39,121	15	37,460	18	1,661	4
Applied research	33,779	13	25,590	12	8,189	19
Development and design	11,610	5	4,627	2	6,983	16
Management or administration	52,838	21	39,983	19	12,855	30
Of R&D	29,286	11	21,153	10	8,133	19
Other than R&D	16,023	6	12,900	6	3,123	7
Both	7,529	3	5,930	3	1,599	4
Teaching	93,665	37	84,073	39	9,592	22
Consulting	5,655	2	3,949	2	1,706	4
Sales	11,824	5	11,433	5	391	1
Other primary work activity	7,691	3	6,426	3	1,265	3
Primary work activity unreported	6,228	—	5,514	—	714	—

[1] Primary work activity is defined as that type of work occupying the largest portion of time.
[2] Including 94 employed doctoral scientists or engineers who did not indicate their field.
[3] Excluding those whose primary work activity was unreported.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1975* (NSF 77-309), pp. 44-47.
See Figure 5-21 in text.

Table 5-14. Employed doctoral scientists and engineers by type of R&D activity and by field, 1975

Field	Primary work activity			
	Total	Research	Development	Management or administration of R&D
	Number			
Total	113,796	72,900	11,610	29,286
Physical and environmental[1] scientists	37,989	25,501	2,342	10,146
Engineers	24,966	9,850	6,983	8,133
Mathematical and computer scientists	5,046	3,046	1,196	804
Life scientists	33,847	26,584	691	6,572
Psychologists and social scientists	11,941	7,917	396	3,628
	Percent distribution across fields			
Total	100	100	100	100
Physical and environmental[1] scientists	33	35	20	35
Engineers	22	14	60	28
Mathematical and computer scientists	4	4	10	3
Life scientists	30	36	6	22
Psychologists and social scientists	10	11	3	12
	Percent distribution across types of primary work activity			
Total	100	64	10	26
Physical and environmental[1] scientists	100	67	6	27
Engineers	100	39	28	33
Mathematical and computer scientists	100	60	24	16
Life scientists	100	79	2	19
Psychologists and social scientists	100	66	3	30

[1] Environmental scientists includes earth scientists, oceanographers, and atmospheric scientists.

NOTE: Percents may not add to 100 because of rounding. The above total column contains 7 whose field of science was not reported.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1975* (NSF 77-309), pp. 50-53.

See Figure 5-22 in text.

Table 5-15. Doctoral R&D scientists and engineers[1] by field and type of employer, 1975

Field	Total	Business and industry	Four-year colleges and universities	Government	Other employers
			Number		
All fields[2]	113,796	45,352	41,776	15,470	11,198
Scientists	88,830	28,489	37,819	12,891	9,631
Physical scientists	31,753	18,010	8,322	3,321	2,100
Mathematical scientists	3,154	711	1,776	495	172
Computer specialists	1,892	1,137	418	185	152
Environmental scientists[3]	6,236	1,553	2,147	1,874	662
Life scientists	33,847	5,711	19,070	5,386	3,680
Psychologists and social scientists	11,941	1,367	6,079	1,630	2,865
Engineers	24,966	16,863	3,957	2,579	1,567
			Percent distribution across fields		
All fields[2]	100	100	100	100	100
Scientists	78	63	91	83	86
Physical scientists	28	40	20	21	19
Mathematical scientists	3	2	4	3	2
Computer specialists	2	3	1	1	1
Environmental scientists[3]	5	3	5	12	6
Life scientists	30	13	46	35	33
Psychologists and social scientists	10	3	15	11	26
Engineers	22	37	9	17	14
			Percent distribution across types of employer		
All fields[2]	100	40	37	14	10
Scientists	100	32	43	15	11
Physical scientists	100	57	26	10	7
Mathematical scientists	100	23	56	16	5
Computer specialists	100	60	22	10	8
Environmental scientists[3]	100	25	34	30	11
Life scientists	100	17	56	16	11
Psychologists and social scientists	100	11	51	14	24
Engineers	100	68	16	10	6

[1] Those whose primary work activity is R&D or R&D management.
[2] Includes 7 who did not report their field.
[3] Includes earth scientists, oceanographers, and atmospheric scientists.

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1975* (NSF 77-309), pp. 50-53.

See Figures 5-23 and 5-24 in text.

Table 5-16. Median annual salaries of doctoral scientists and engineers whose fields of employment differed from their doctoral fields, by number of years since the doctorate, 1973

Years since earning doctorate	Those employed outside their doctoral field	Those employed within their doctoral field
Total	$22,300	$20,500
1-3 yrs.	17,200	16,600
4-7 yrs.	19,700	18,800
8-13 yrs.	23,000	21,700
14-23 yrs.	26,200	25,200
24-43 yrs.	28,600	27,200

SOURCE: National Academy of Sciences, *Field Mobility of Doctoral Scientists and Engineers*, 1975, p. 66.

See Figure 5-25 in text.

Table 5-17. Women science and engineering doctorate recipients by field, 1965-75

Year	Total	Physical sciences	Engineering	Mathematical sciences[1]	Life and environmental sciences	Social sciences[2]
			Number			
1965	744	127	7	50	263	297
1966	911	132	8	48	326	397
1967	1,086	161	9	48	401	467
1968	1,295	185	12	47	483	568
1969	1,472	205	10	56	537	664
1970	1,626	243	15	77	538	753
1971	1,929	244	16	96	656	917
1972	2,101	269	21	96	680	1,035
1973	2,446	257	45	119	795	1,230
1974	2,590	260	34	115	784	1,397
1975	2,838	284	50	110	863	1,531
1976	2,997	296	53	113	870	1,665
		As a percent of all doctorate recipients				
1965	7	4	(3)	7	10	13
1966	8	4	(3)	6	12	15
1967	8	5	(3)	6	14	15
1968	9	5	(3)	5	14	17
1969	9	5	(3)	5	14	17
1970	9	6	(3)	6	13	17
1971	10	5	1	8	15	18
1972	11	6	1	7	15	19
1973	13	6	1	10	17	21
1974	14	7	1	10	18	24
1975	15	8	2	10	19	25
1976	17	9	2	11	19	27

[1] Includes computer specialists.
[2] Excludes history.
[3] Less than 0.5 percent.

SOURCE: National Academy of Sciences, *Doctorate Recipients from U.S. Universities*, annual series.

See Figure 5-29 in text.

Table 5-18. Minority representation among scientists and engineers by field, 1974

Field	Total scientists and engineers (thousands)	Minorities as percent of total			
		All minorities	Black	Asian	Other minorities
Total	1,973.2	4.4	1.6	1.9	0.9
Engineers	1,071.8	3.5	.8	1.9	.8
Mathematical scientists	60.4	5.8	3.1	2.2	.5
Computer scientists	125.5	4.5	2.0	1.9	.6
Life scientists	193.9	5.0	1.8	1.4	1.8
Physical and environmental scientists	240.3	4.5	1.5	2.1	.9
Social scientists and psychologists	281.4	7.1	4.2	1.7	1.2

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *U.S. Scientists and Engineers: 1974* (NSF 76-329), pp. 24-25.

See Figure 5-30 in text.

Table 5-19. Annual average unemployment rates, 1963-76

Year	Total labor force	Professional and technical workers	Scientists		Engineers	
			Total	Doctoral	Total	Doctoral
1963	5.7	1.9	NA	NA	1.2	NA
1964	5.1	1.8	NA	NA	1.5	NA
1965	4.6	1.5	NA	NA	1.1	NA
1966	3.9	1.3	.4	NA	.7	NA
1967	3.7	1.3	NA	NA	.6	NA
1968	3.6	1.2	.9	.5	.7	NA
1969	3.5	1.3	NA	NA	.8	NA
1970	5.0	2.0	1.6	.9	2.2	NA
1971	6.0	3.0	2.6	1.4	2.9	1.9
1972	5.6	2.4	NA	NA	2.0	NA
1973	4.9	2.2	NA	1.2	1.0	.8
1974	5.6	2.3	.9	NA	1.3	NA
1975	8.5	3.1	NA	1.0	2.6	.7
1976	7.7	3.2	NA	NA	1.7	NA

SOURCE: Bureau of Labor Statistics, Department of Labor, and National Science Foundation, unpublished data.

See Figure 5-33 in text.

Table 5-20. Percent distribution of the fields of college major chosen by National Merit Scholars, 1966-76

Field	Percent distribution										
	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Science and engineering	62.3	63.8	66.6	66.6	68.6	68.1	69.1	68.3	69.8	68.5	70.4
Engineering	8.6	10.4	10.6	9.9	12.9	9.4	8.5	9.0	11.2	14.2	16.5
Science	53.7	53.5	56.0	56.7	55.7	58.7	60.7	59.3	58.6	54.3	53.9
Physical and natural sciences	36.2	36.6	37.0	36.2	36.9	36.4	33.5	32.6	32.4	28.2	29.8
Physical sciences	14.2	13.3	11.9	11.1	12.4	10.1	8.5	8.0	8.9	7.1	8.6
Chemistry	6.0	5.4	4.1	3.7	4.6	4.0	2.9	2.6	3.1	2.6	3.0
Physics	7.6	7.0	6.9	6.4	6.2	5.0	4.2	4.4	4.4	3.6	4.4
Other physical sciences	.6	.9	.9	1.0	1.7	1.1	1.5	1.0	1.4	.9	1.2
Life sciences	6.2	5.2	3.3	4.3	3.2	4.2	4.1	4.4	4.6	4.1	6.2
Mathematics	14.1	15.4	12.2	12.2	11.8	12.8	10.1	10.1	7.8	6.8	8.0
Unspecified physical and natural sciences	1.7	2.7	9.6	8.5	9.5	9.3	10.8	10.2	11.1	10.2	9.7
Pre-medicine	5.2	4.4	5.8	6.4	5.9	7.2	11.0	11.3	10.1	11.4	11.3
Social sciences	12.3	12.4	13.2	14.1	12.9	15.2	16.1	15.4	16.1	14.7	12.8
All other fields and "undecided"	37.7	36.2	33.4	33.4	31.4	31.9	30.9	31.7	30.2	31.4	29.0
Health professions	1.5	1.0	.9	1.8	1.6	1.5	2.5	2.5	1.9	2.9	2.3
All other fields	24.1	23.3	28.2	27.6	26.1	26.3	24.9	25.6	23.5	24.1	22.6
Undecided	12.1	11.8	4.3	4.0	3.7	4.1	3.5	3.6	4.8	4.4	4.1

NOTE: Detail may not add to totals because of rounding.

SOURCE: National Merit Scholarship Corporation, *National Merit Scholarship Corporation Annual Report*, annual series.

See Figure 5-34 in text.

Table 5-21. Distribution of occupational preferences of college freshmen, 1968-76

Probable career occupation	1968	1969	1970	1971	1972	1973	1974	1975	1976
Total	100	100	100	100	100	100	100	100	100
Artist (including performer)	6	6	6	6	7	4	6	5	7
Business	11	11	11	11	11	16	13	14	16
Clergy	1	1	1	1	1	1	1	1	1
College teacher	1	1	1	1	1	1	1	1	([1])
Doctor (M.D. or D.D.S.)	4	3	4	4	6	6	5	5	5
Educator	24	22	19	15	12	9	8	7	8
Secondary	14	13	11	9	7	5	4	4	4
Elementary	9	9	8	7	6	4	4	3	4
Engineer	8	8	8	5	5	5	5	6	8
Farmer or forester	2	2	2	3	3	3	4	4	3
Health professional (non-M.D.)	4	4	5	6	7	8	9	9	7
Lawyer	3	4	4	4	5	5	4	4	4
Nurse	3	3	4	4	5	5	5	5	5
Research scientist	3	3	3	3	2	3	2	2	2
Other occupations	20	22	22	24	23	23	26	25	23
Undecided	11	11	12	13	14	11	12	14	10

NOTE: Detail may not add to totals because of rounding.

[1] Less than 0.5 percent.

SOURCE: American Council on Education and University of California, Los Angeles, *The American Freshman: National Norms*, annual series.

See Figure 5-35 in text.

Table 5-22. Changes in enrollment of junior-year undergraduate students by field of major, 1973 and 1974

Field of major	Number (in thousands) Fall 1973	Fall 1974	Percent change
Total junior-year enrollment	1,080.4	1,101.6	2.0
Those with a declared major	984.0	997.2	1.3
Science and engineering	324.6	328.3	([1])
Natural science and engineering	179.6	187.7	4.5
Agriculture and natural resources	29.0	31.6	9.0
Computer and information sciences	6.5	7.1	9.0
Engineering	43.7	45.6	([1])
Biological sciences	64.6	68.2	5.5
Basic medical sciences	5.1	5.9	14.1
Biology and botany	39.5	41.2	4.4
Zoology	5.8	5.8	-1.2
Other biological sciences	10.1	11.3	11.9
Mathematics	22.2	19.7	-11.0
Physical sciences	25.7	26.7	([1])
Chemistry	12.4	13.1	([1])
Geology	4.1	4.4	([1])
Physics	5.0	4.7	([1])
Other physical sciences	3.7	4.0	8.0
Social sciences	142.4	138.0	-3.1
Economics	14.0	15.2	8.6
Political science and government	31.5	31.3	([1])
Psychology	49.5	48.9	([1])
Sociology	34.3	30.0	-12.6
Other basic social sciences	13.1	12.5	([1])
Other fields	647.2	657.7	1.6
Arts and humanities	144.3	139.0	-3.7
Business and management	146.4	158.5	8.2
Education	135.4	127.3	-5.9
Engineering technologies	11.8	11.9	([1])
Health professions	59.7	67.4	12.9
History	32.1	28.9	-9.9
Other social sciences	26.9	28.3	5.4
All other fields	90.7	96.3	6.2
Majors undeclared	96.4	104.4	8.3

[1] This apparent change could have been the result of sampling variation.

NOTE: Data presented are weighted estimates based on responses from 482 out of a sample of 530 colleges and universities. Details may not add to totals as each item, total, and subtotal was estimated separately. Percentage changes were calculated on unrounded data.

SOURCE: Irene L. Gomberg and Frank L. Atelsek, *Major Field Enrollment of Junior Year Students, 1973 and 1974,* (Washington, D.C.: American Council on Education, 1976), pp. 6, 24.

See Figure 5-36 in text.

Table 5-23. Bachelor's and first-professional degrees awarded by field, 1960-75

Year	All fields	Science and engineering fields: Total	Physical and environmental sciences	Engineering	Mathematical sciences	Life and agricultural sciences	Social sciences[2]	All other fields[1]
	Number							
1960	394,889	120,937	16,057	37,808	11,437	24,141	31,494	273,952
1961	401,784	121,660	15,500	35,866	13,127	23,900	33,267	280,124
1962	420,485	127,469	15,894	34,735	14,610	25,200	37,030	293,016
1963	450,592	135,964	16,276	33,458	16,128	27,801	42,308	314,628
1964	502,104	153,361	17,527	35,226	18,677	31,611	50,320	348,743
1965	538,930	164,936	17,916	36,795	19,668	34,842	55,715	373,994
1966	555,613	173,471	17,186	35,815	20,182	36,964	63,424	382,142
1967	594,862	187,849	17,794	36,188	21,530	39,408	72,929	407,013
1968	671,591	212,174	19,442	37,614	24,084	43,260	87,774	459,417
1969	769,683	244,519	21,591	41,553	28,263	48,713	104,399	525,164
1970	833,322	264,122	21,551	44,772	29,109	52,129	116,561	569,200
1971	884,386	271,176	21,549	45,387	27,306	51,461	125,473	613,210
1972	937,884	281,228	20,887	46,003	27,250	51,484	133,604	656,656
1973	980,707	295,391	20,809	46,989	27,528	59,486	140,579	685,316
1974	1,008,654	305,062	21,287	43,530	26,570	68,226	145,449	703,592
1975	987,922	294,920	20,896	40,065	23,385	72,710	137,864	693,002
	As a percent of all fields							
1960	100	31	4	10	3	6	8	69
1961	100	30	4	9	3	6	8	70
1962	100	30	4	8	4	6	9	70
1963	100	30	4	7	4	6	9	70
1964	100	31	4	7	4	6	10	69
1965	100	31	3	7	4	7	10	69
1966	100	31	3	6	4	7	11	69
1967	100	32	3	6	4	7	12	68
1968	100	32	3	6	4	6	13	68
1969	100	32	3	5	4	6	14	68
1970	100	32	3	5	4	6	14	68
1971	100	31	2	5	3	6	14	69
1972	100	30	2	5	3	6	14	70
1973	100	30	2	5	3	6	14	70
1974	100	30	2	4	3	7	14	70
1975	100	30	2	4	2	7	14	70

[1] Including first-professional degrees such as M.D., D.D.S., D.V.M., and J.D. degrees.
[2] Excluding history.

NOTE: Percents may not add to 100 because of rounding.

SOURCE: National Center for Education Statistics, *Earned Degrees Conferred*, annual series, and National Science Foundation, unpublished data.

See Figure 5-37 in text.

Table 5-24. Enrollment for advanced degrees[1] by field, 1960-75

Fall term	All fields	Science and engineering fields: Total	Physical and environ-mental sciences	Engi-neering	Mathe-matical sciences	Life and agri-cultural sciences	Social sciences[2]	All other fields
	Number							
1960	314,349	120,638	25,707	36,636	11,770	19,715	26,810	193,711
1961	338,981	128,794	26,553	39,367	12,671	21,446	28,757	210,187
1962	373,845	142,433	28,591	43,850	14,121	23,953	31,918	231,412
1963	413,366	158,051	30,959	48,917	15,974	26,888	35,313	255,315
1964	477,535	178,123	34,061	54,318	18,805	30,787	40,152	299,412
1965	535,332	195,346	36,506	57,516	21,014	34,749	45,561	339,986
1966	583,000	207,049	37,950	58,338	23,150	37,007	50,604	375,951
1967	649,697	224,468	40,477	62,633	25,066	39,954	56,368	425,229
1968	703,745	234,661	40,937	63,662	26,840	41,676	61,546	469,084
1969	756,865	243,715	39,885	65,048	29,175	44,203	65,404	513,150
1970	816,207	252,159	40,113	64,788	30,608	46,260	70,390	564,048
1971	836,294	246,100	38,928	59,321	28,847	47,662	71,342	590,194
1972	858,580	242,988	36,047	55,847	28,064	49,118	73,912	615,592
1973	908,101	244,354	35,995	54,567	27,023	50,714	76,055	663,747
1974	965,000	250,673	34,936	56,001	27,118	54,225	78,393	714,327
1975	1,053,769	261,522	35,497	59,304	27,024	58,049	81,648	792,247
	As a percent of all fields							
1960	100	38	8	12	4	6	9	62
1961	100	38	8	12	4	6	9	62
1962	100	38	8	12	4	6	9	62
1963	100	38	8	12	4	7	9	62
1964	100	37	7	11	4	6	8	63
1965	100	37	9	11	4	7	9	63
1966	100	36	7	10	4	6	9	64
1967	100	35	6	10	4	6	9	65
1968	100	33	6	9	4	6	9	67
1969	100	32	5	9	4	6	9	68
1970	100	31	5	8	4	6	9	69
1971	100	29	5	7	3	6	9	71
1972	100	28	4	7	3	6	9	72
1973	100	27	4	6	3	6	8	73
1974	100	26	4	6	3	6	8	74
1975	100	25	3	6	3	6	8	75

[1] Excluding enrollment for first-professional degrees such as M.D., D.V.M., D.D.S., and J.D.
[2] Excluding history.

NOTE: Percents may not add to 100 because of rounding.

SOURCE: National Center for Education Statistics, *Students Enrolled for Advanced Degrees*, annual series, and National Science Foundation, unpublished data.

See Figure 5-38 in text.

Table 5-25. Master's degrees awarded by field, 1960-75

Year	All fields	Science and engineering fields: Total	Physical and environmental sciences	Engineering	Mathematical sciences	Life and agricultural sciences	Social sciences[1]	All other fields
	Number							
1960	74,497	20,012	3,387	7,159	1,765	3,751	3,950	54,485
1961	78,269	22,786	3,799	8,178	2,238	4,085	4,486	55,483
1962	84,889	25,146	3,929	8,909	2,680	4,672	4,956	59,743
1963	91,418	27,367	4,132	9,635	3,323	4,718	5,559	64,051
1964	101,122	30,271	4,567	10,827	3,603	5,357	5,917	70,851
1965	112,195	33,835	4,918	12,056	4,294	5,978	6,589	78,360
1966	140,772	38,083	4,992	13,678	5,610	6,666	7,737	102,689
1967	157,892	41,800	5,412	13,885	5,733	7,465	9,305	116,092
1968	177,150	45,425	5,508	15,188	6,081	8,315	10,333	131,725
1969	194,414	48,425	5,911	15,243	6,735	8,809	11,727	145,989
1970	209,387	49,318	5,948	15,597	7,107	8,590	12,076	160,069
1971	231,486	50,624	6,386	16,347	6,789	8,320	12,782	180,862
1972	252,774	53,567	6,307	16,802	7,186	8,914	14,358	199,207
1973	264,525	54,234	6,274	16,758	7,146	9,080	14,976	210,291
1974	278,259	54,175	6,087	15,393	7,116	9,605	15,974	224,084
1975	293,651	53,852	5,830	15,434	6,637	9,618	16,333	239,799
	As a percent of all fields							
1960	100	27	5	10	2	5	5	73
1961	100	29	5	10	3	5	6	71
1962	100	30	5	11	3	6	6	70
1963	100	30	5	11	4	5	6	70
1964	100	30	5	11	4	5	6	70
1965	100	30	4	11	4	5	6	70
1966	100	27	4	10	4	5	6	73
1967	100	26	3	9	4	5	6	74
1968	100	26	3	9	3	5	6	74
1969	100	25	3	8	4	5	6	75
1970	100	24	3	7	3	4	6	76
1971	100	22	3	7	3	4	6	78
1972	100	21	3	7	3	4	6	79
1973	100	21	2	6	3	3	6	79
1974	100	19	2	6	3	3	6	81
1975	100	18	2	5	2	3	6	82

[1] Excluding history.

NOTE: Percents may not add to 100 because of rounding.

SOURCE: National Center for Education Statistics, *Earned Degrees Conferred,* annual series, and National Science Foundation, unpublished data.

See Figure 5-39 in text.

Table 5-26. Doctoral degrees[1] awarded by field, 1965-76

Year	All fields	Science and engineering fields: Total	Physical sciences	Engi-neering	Mathe-matical sciences[2]	Life sciences[3]	Social sciences	All other fields
1965	16,340	10,477	2,865	2,073	685	2,539	2,315	5,863
1966	17,953	11,456	3,058	2,299	769	2,712	2,618	6,497
1967	20,384	12,982	3,502	2,603	830	2,967	3,080	7,402
1968	22,916	14,411	3,667	2,847	970	3,501	3,426	8,505
1969	25,724	15,949	3,910	3,249	1,064	3,796	3,930	9,775
1970	29,475	17,731	4,400	3,432	1,222	4,163	4,514	11,744
1971	31,772	18,880	4,494	3,495	1,236	4,533	5,122	12,892
1972	33,001	18,940	4,226	3,475	1,281	4,505	5,453	14,061
1973	33,727	18,948	4,016	3,338	1,222	4,574	5,798	14,779
1974	33,000	18,316	3,696	3,144	1,196	4,407	5,873	14,684
1975	32,913	18,352	3,611	2,959	1,149	4,540	6,093	14,561
1976	32,923	17,832	3,442	2,791	1,003	4,480	6,116	15,091
	As a percent of all fields							
1965	100	64	18	13	4	16	14	36
1966	100	64	17	13	4	15	15	36
1967	100	64	17	13	4	15	15	36
1968	100	63	16	12	4	15	15	37
1969	100	62	15	13	4	15	15	38
1970	100	60	15	12	4	14	15	40
1971	100	59	14	11	4	14	16	41
1972	100	57	13	11	4	14	17	43
1973	100	56	12	10	4	14	17	44
1974	100	56	11	10	4	13	18	45
1975	100	56	11	9	3	14	19	44
1976	100	54	10	8	3	14	19	46

[1] Excluding first-professional degrees such as M.D., D.D.S., D.V.M., and J.D.
[2] Including computer specialists.
[3] Including environmental sciences.

SOURCE: National Academy of Sciences, *Doctorate Recipients from U.S. Universities*, annual series.

See Figure 5-40 in text.

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Index to Indicator Tables

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Productivity

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